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Cover image: The chalk-hill blue (*Polyommatus coridon*, Lycaenidae) – the insect of the year for Germany, Austria, and Switzerland. See T. Schmitt's article on page 107.

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Biology and biogeography of the chalk-hill blue *Polyommatus coridon* – insect of the year 2015 for Germany, Austria and Switzerland

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Abstract. The chalk-hill blue was nominated insect of the year 2015 for Germany, Austria and Switzerland. The species is strongly associated with base-rich short-turfed swards; the caterpillars feed mainly on horseshoe vetch *Hippocrepis comosa* and show myrmecophilous behaviour. The species is restricted to Europe, where it is widely distributed but missing from the northern parts of the continent. *Polyommatus coridon* survived the last ice age in Mediterranean refugia in Italy and the Balkan Peninsula from where it colonised more northern regions postglacially.

The chalk-hill blue – insect of the year 2015 for Germany, Austria and Switzerland

The insect of the year for Germany, Austria and Switzerland has been nominated by a curatorium every year since 1999. This panel is composed of experts representing a variety of scientific societies and institutions in these three countries. The goal is to advertise insects in general to a broader public by focusing on one charismatic species every year. However, the aesthetic appeal of the selected species is not the most important aspect of the insect of the year. Beauty in this case is just a vehicle to stimulate interest in the highly remarkable ecology and behaviour of the species. In particular, the nomination of an insect of the year is intended to enhance awareness of the general importance of insects and the necessity of their conservation. After nomination of the brimstone *Gonepteryx rhamni* in 2002 and the burnet *Zygaena carniolica* in 2008, the chalk-hill blue *Polyommatus coridon* (Poda, 1761) (Figure 1) became the third lepidopteran species to be nominated insect of the year, in 2015. Against this background, an overview of the biology and biogeography of this butterfly species is presented.

Portrait of the species

The wing pattern of the chalk-hill blue is remarkably dimorphic. The colour of the upperside of the wings is light blue in the male, often with a silvery hue. The margin of the forewings is brown, but the width of this varies regionally. A pattern of white circles can be observed in this margin. However, this patterning is much less frequent in eastern than in western European populations (Schmitt et al. 2005). On the hindwing, this margin is mostly dissected into brown spots with white margins.

Figure 1. A freshly emerged male of the chalk-hill blue with open wings sitting on the dry inflorescence of a knapweed. Spiazzi, Monte Baldo, northern Italy, 02.IX.2013. Photo: Thomas Schmitt.

The dominating colour of the wing upperside of the females is brown. The hindwings in most cases show orange spots at the margin. These spots are less pronounced on the forewing and fade out towards the apex. The darker central spot on the forewing is often bordered by a narrow white line (Figure 2).

The underside of both wings has a characteristic spot pattern, which is similar in males and females. The dark spots are always surrounded by white lines. The colour of the underside of the wings is always lighter in males than in females. In males this is a slightly yellowish light brown or pale grey, whereas in females it is a considerably darker brown (Figure 3).

The larvae have a typically lycaenid shape. Their dominant colour is greenish, but with a somewhat dirty aspect. Two broken yellow lines run dorsally along the entire body. Other yellow markings can be found laterally (Figure 4).

Closely related species

In central Europe, the male of the chalk-hill blue can hardly be mixed up with any other lycaenid. A somewhat similar blue is only observed in *Polyommatus damon* and *Polyommatus daphnis*, but these two species show considerably different wing patterning (Settele et al. 2009). However, the situation becomes much more complicated in south-western Europe. *Polyommatus hispana* is widely distributed in eastern Spain, southern France and a geographically rather limited area

Figure 2. Copula of the chalk-hill blue with open wings sitting on the inflorescence of a blue-flowering *Eryngium* species. The differences in wing pattern between female (left) and male (right) are easily recognised. Spiazzi, Monte Baldo, northern Italy, 02.IX.2013. Photo: Thomas Schmitt.

in north-western Italy. This sibling species is morphologically mostly similar to *P. coridon*, but allozyme polymorphisms strongly supports it status as a distinct species (Schmitt et al. 2005). Also *Polyommatus albicans*, widely distributed in central Iberia, but also in the Atlas Mountains of Morocco, is difficult to distinguish if relying on its morphology alone; however, the colour of the wings in general is more whitish than in *P. coridon*.

The species status of *Polyommatus philippi*, which is restricted to a limited region in north-eastern Greece, is highly controversial and it has often been synonymised with *P. coridon*. Also the morphologically differing *P. coridon caelestissima*, which is endemic to a restricted area in eastern Spain geographically separated from the continuous distribution of the species, has a doubtful taxonomic status. In this case, the males have a sky-blue and not a light silvery blue wing colour; it is still debated whether this taxon represents a well differentiated subspecies or a separate species (Fernández-Rubio 1991, Tolman and Lewington 1998, Tshikolovets 2011).

The populations in the mountain areas of the islands of Corsica and Sardinia were only discovered in the 1970s and 1980s, respectively, and were described as *P. coridon nufrellensis* and *P. coridon gennargenti*. While the former is mostly accepted as being just a subspecies of *P. coridon*, the latter is frequently assumed to be a good species, as supported for example by genetic analysis and rearing experiments (Marchi et al. 1996, Jutzeler et al. 2003). *Polyommatus corydonius* is

Figure 3. Copula of the chalk-hill blue with closed wings. The differences in wing pattern between female (left) and male (right) are easily recognised. Csákvár, Vértes mountains, western Hungary, 08.VIII.2014. Photo: Thomas Schmitt.

another morphologically similar species distributed in Turkey and the Caucasus region, but which never occurs in sympatry with *P. coridon* (Tshikolovets 2011).

The female of *P. coridon* is much more easily misidentified than the male as it is rather similar to several other species. Even females of *Polyommatus bellargus*, which is well differentiated in males by the sky-blue wing colour, are not easy to distinguish. One of the clearest characters of the female *P. coridon* is the distribution of the intensity of the brown colour on the underside of the forewing: the relatively dark brown at the margins becomes gradually lighter to the centre. However, particularly in old and hence worn females, this cannot be assessed without doubt remaining in some cases (Tolman and Lewington 1998, Tshikolovets 2011).

Due to the close relatedness within the genus *Polyommatus*, natural interspecific hybrids are frequently observed, as for example between *P. coridon* and *P. bellargus* (e.g. de Lesse 1969a). These hybrids have an intermediate pattern and colouring of the wings and are named *Polyommatus* × *polonus*.

Life cycle

The chalk-hill blue is strictly univoltine over most of its range. Males in most regions start emerging by mid-July. A peak of male emergence can often be observed around 20 July. Early males may

Figure 4. The caterpillar of the chalk-hill blue shortly before pupation, on its host plant horse-shoe vetch, being visited by an ant. Photo: Albert Krebs (E-Pics ETH Zürich). Publication with permission of the copyright holders.

occur in the first half of July or even in late June, but are relatively rare (Ebert and Rennwald 1991, Haag and Eller 2007, Trampenau 2007, Pfeuffer 2013); exceptionally early sightings were recorded for Bavaria where butterflies were observed in the wild as early as 15 May (Pfeuffer 2013). Such early males might be predestined for hybridisation with females of the first generation of *P. bellargus*. However, even in rather warm and dry years, the normal flight season of *P. coridon* is only marginally earlier than in normal years. Females mostly emerge one week later than males, hence showing protandry (Thiel and Meyer 2007), as in many other butterflies and insects in general. The flight season of the chalk-hill blue is relatively long, but the number of individuals starts to decline around 20 August in most years. Nevertheless, the species is frequently still to be observed in early September, but mostly in relatively small numbers. Observations in the second half of September have only been made in some years. Sightings in early October exist, but are exceptions.

Truly bivoltine populations are only known in a geographically restricted area of south-western Slovakia in the Vah valley. They were even described as a separate species, *Polyommatus slovacus* (Vít'az et al. 1997). However, analyses of allozyme polymorphisms clearly demonstrated that these bivoltine populations show no genetic differentiation from the nearest univoltine populations; furthermore, no indication of a genetic bottleneck could be detected; therefore, their species status has to be rejected (Schmitt et al. 2005). In these bivoltine populations of south-western Slovakia, a first generation by the end of May and in June composed of relatively small numbers of individuals is followed by a second generation, which normally is much more numerous than the first generation and on the wing during the normal flight period of univoltine populations of adjoining regions (Schmitt et al. 2005).

The closely related *P. hispana* in eastern Spain and southern France (Kudrna et al. 2011) also has two generations a year, but the first one is on the wing earlier than in the Vah valley, while the second one tends to be later than *P. coridon* (Tolman & Lewington, 1998). All other closely related species only have a single generation per year, with adults flying in mid-summer (Tshikolovets 2011).

Populations of *P. coridon* other than that in the Vah valley are strictly univoltine. Schurian (1989) reports that it is not possible to obtain the next generation of butterflies without diapause, albeit under artificial breeding conditions. However, Comont et al. (2009) obtained spontaneous development of British provenances, with adults reared in a green house but under conditions similar to the normal climatic environmental conditions emerging by mid-November. A similar phenomenon also might explain the few exceptionally early butterflies observed in Bavaria (see above).

The females lay their eggs after being fertilised. Often the eggs are not laid directly on the larval host plant, but on dry grass or moss nearby. If eggs are laid directly on the larval host plant, this is not on living parts of the plant like shoots and flowers, but on dry parts (Ebert and Rennwald 1991, Pfeuffer 2000). The young larva, when ready to hatch, remains in the egg shell for the entire winter (but see Comont et al. 2009). It only hatches in the following spring when the sun heats its surroundings to an adequate temperature. Hatching thus takes place from mid-March onwards. The caterpillars then develop relatively quickly, but considerably more slowly than related lycaenid species with more than one generation per year. Pupation takes place close to the ground, close to the host plants, in early June or later. The pupal stage lasts about one month, so that the imagoes hatch punctually by mid-July, thereby completing one complete life cycle (Ebert and Rennwald 1991).

Habitats

The chalk-hill blue has relatively demanding habitat requirements (Brereton et al. 2008). The most typical habitats in central Europe are semi-natural calcareous grasslands such as Mesobrometum (Figure 5) and Xerobrometum, but also the Coelerietum, often in the form of pastured *Juniperus* heathlands (Figure 6) (Ebert and Rennwald 1991, Haag and Eller 2007, Pfeuffer 2013). Additionally, the sparse vegetation which rapidly becomes established in abandoned limestone queries and is often remarkably similar structurally to the above mentioned grasslands can be suitable habitats too (Lotzing 1990, Beneš and Konvička 2002, Höttinger et al. 2013). At some places, as for example in the Nahe valley (Rhineland-Palatinate, Germany) or in northern Bohemia, *P. coridon* is also present on base-rich soils over vulcanitic rocks, especially on rocky slopes with sparse vegetation and on *Stipa* grasslands. Occurrences on acid or neutral soils are really rare in western Europe (e.g. the Rotenfels in the Nahe valley, Rhineland-Palatinate, Germany). Occurrences on such soils are somewhat more common, but still rare, in eastern and south-eastern Europe. This difference might be also due to the regional differences in the level of larval host plant specialisation with western European populations being more specific than eastern ones (see below).

In some regions, in particular in eastern Brandenburg (e.g. on the slopes along the river Oder), large populations are also found on base-rich sandy soils, where the preferred habitats are *Stipa* grasslands. However, occurrences on sandy soils are rather rare elsewhere. One of these exceptions is the Mainzer Sand in Rhineland-Palatinate (Germany).

Large populations of the chalk-hill blue can also be observed in the southern part of the species range. However, here it retreats from the hot plains and valleys and inhabits the somewhat cooler hills and mountains. The karst regions of the Balkan Peninsula (Figure 7) and the Apennines in Italy are regions of southern Europe with a particularly high number of suitable habitats.

Figure 5. The Mesobrometum represents a characteristic habitat of the chalk-hill blue. The photos show a typical habitat in spring when the caterpillars are shortly before pupation. Nature Reserve Perfeist near Wasserliesch (Rhineland-Palatinate, Germany), 10.V.2009. Photos: Thomas Schmitt.

Figure 6. Flower-rich *Juniperus* heathlands, which belong to the plant association Coelerietum, are among the best habitats for the chalk-hill blue. The photos show the summer aspect when the butterflies are on the wing. Bucovica, Durmitor, Montenegro, 31.VII.2014. Photos: Thomas Schmitt.

In calcareous mountain ranges, the butterflies can be found on highly inaccessible rocky slopes (Fig. 8) where they inhabit small patches of grassland on steep slopes and within rocky fields. Here, the imagoes use the existing flowers for nectaring and the larvae feed on their host plants, which can be found between stones. However, the population densities are generally lower in these habitats than they are in the most suitable ones.

Although the chalk-hill blue is considered to be a moderately thermophilic species, individual-rich populations are observed in the Alps as high as 2000 m asl. However, the numbers of individuals decreases considerably above 2000 m asl., with only occasional observations documented from above 2500 m asl. (Schweizerischer Bund für Naturschutz 1987, Huemer 2004, Stettmer et al. 2007). It is remarkable that individuals in the Alps are also found in regions with acidic ground rock where this is intermixed with other more base-rich rock or even limestone. This phenomenon can for example be observed in the Großglockner and the Matterhorn regions.

Figure 7. The karst landscapes in the southern European mountain regions have many habitats suitable for the chalk-hill blue. The habitat here is in the border region of Bulgaria and Greece at an altitude of about 1500 m asl. Trigrad, southern Bulgaria, 04.VIII.2010. Photo: Thomas Schmitt.

Ecology of the larvae

The caterpillars preferably feed on the horse-shoe vetch *Hippocrepis comosa* (Figure 9). This species apparently is the exclusive larval host plant in the western part of the range. In more eastern regions from the Balkan Peninsula in the South to Brandenburg and Poland in the North, the larvae also feed on the purple crown vetch *Securigera varia* (Abb. 10) (Beneš and Konvička 2002, Höttinger et al. 2013). In some regions without populations of horse-shoe vetch, as in Poland, eastern Brandenburg and Saxony, purple crown vetch can even be the only host plant of the caterpillars (Trampenau 2007, Buszko and Masłowski 2008, Settele et al. 2009). Some authors also mention the liquorice milkvetch *Astragalus glycyphyllos* (Schweizerischer Bund für Naturschutz 1987, Höttinger et al. 2013); however, this host plant might be generally of minor importance. Tshikolovets (2011) additionally mentions *Hippocrepis glauca*, a species restricted to the Mediterranean region. For the populations from Corsica, *Hippocrepis conradiae*, endemic to this island, was mentioned as a host plant (Parmentier and Zinszner 2013). Searching for the caterpillars is relatively easy, as they can frequently be found beneath larger individuals of their host plants, often in the moss layer (Ebert and Rennwald 1991).

The caterpillars are often accompanied by ants, with which they live in symbiosis (e.g. Schurian 1989, Ebert and Rennwald 1991, Fiedler et al. 1992, Pfeuffer 2000, Asher et al. 2001). The chalk-hill

Figure 8. The chalk-hill blue is also found on rocky cliffs with limited accessibility. The butterflies use the small grassy habitat patches, which are scattered over the steep slopes. Baile Herculane, Cerna valley, south-western Romania, 29.VII.2010. Photo: Thomas Schmitt.

blue is hence a myrmecophilous butterfly species, as are many lycaenids (Figure 4). Both partners benefit from this association (but see Malicky 1969, 1970 for an alternative opinion). The caterpillars have special glands from which they secret a liquid rich in sugar and amino acids, which is taken up by the ants (Maschwitz et al. 1975, Daniels et al. 2005). Fiedler and Maschwitz (1988) were even able to show that the amount of honeydew-like secret production is sufficiently high to "contribute significantly to the nutrition of the attending ants".

In return, the ants defend "their" caterpillars against enemies. Thus, they hinder for example parasitoids such as parasitic wasps and flies from laying their eggs on the larvae. However, the presence of the ants might also be a general protection against other, more opportunistic, predators. Hence, the carnivorous ants protect an otherwise suitable prey. However, this protection is far from being perfect; many caterpillars of the chalk-hill blue are still infested by parasitoids. Nevertheless, even the pupae are frequently found close to ant nests (Pfeuffer 2000, Asher et al. 2001). This symbiosis has already been observed for different ant species. In central Europe, relationships with *P. coridon* are known to involve the genera *Lasius*, *Tetramorium* and *Myrmica* (e.g. Fiedler 1987, Maschwitz and Fiedler 1988, Schurian 1989, Ebert and Rennwald 1991, Fiedler et al. 1992, Pfeuffer 2000, 2013).

In general, myrmecophilous behaviour has frequently been observed in many lycaenid species, with many ant species involved all around the world (e.g. Fiedler et al. 1991, New 1993). The

Figure 9. The horse-shoe vetch *Hippocrepis comosa* is the most important larval host plant of the chalk-hill blue. In the western part of its distribution, this plant species is even the only host plant. An inflorescence is shown to the left, the typical pinnate leaves to the right. Gánt, Vértes mountains, western Hungary, 21.VII.2014. Photos: Thomas Schmitt.

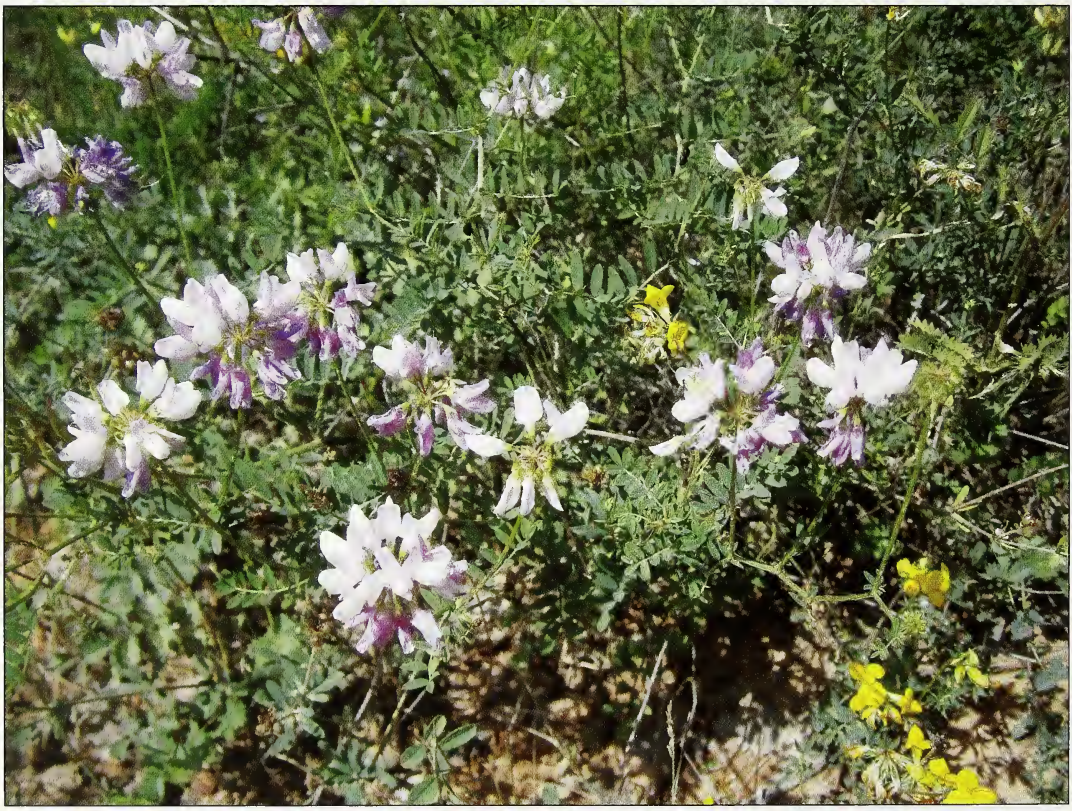

Figure 10. The purple crown vetch *Securigera varia* is an important additional larval host plant from the Balkan Peninsula to eastern Brandenburg and Poland. In some regions, e.g. Brandenburg, this plant is the sole larval host plant. Strausberg, eastern Brandenburg, 17.VI.2014. Photo: Thomas Schmitt.

protective benefits for the larvae of lycaenids have already been demonstrated in the wild for *Glaucopsyche lygdamus* (Pierce and Mead 1981, Pierce and Easteal 1986). Furthermore, higher growth rates of lycaenid larvae with than without ant attendance have been demonstrated (e.g. Fiedler and Saam 1994, Wagner and del Rio 1997).

Ecology of the imagoes

The butterflies are much less choosy in the selection of their nectar sources than the caterpillars are with their host plants. However, the imagoes tend to prefer classic butterfly flowers, mostly of the plant families Lamiaceae, Asteraceae and Caprifoliaceae, although species of Leguminosae are also frequently visited for nectaring. The most visited plant genera are apparently *Origanum*, *Scabiosa*, *Knautia* and *Centaurea* (Weidemann 1986, Ebert and Rennwald 1991, Lörtscher et al. 1995, Pfeuffer 2013). The distribution of nectar sources strongly influences the microdistribution of the butterflies within the habitat (Lörtscher et al. 1995). It seems that butterflies give preference to violet flower heads, but visits to white and yellow flowers can also frequently be observed (Fig. 11). However, the butterflies also gather at muddy places to take up water (e.g. Pfeuffer 2013) and even visit excrements and carcasses (e.g. Jones 2000). Like many other lycaenids, the chalk-hill blue aggregates in sleeping groups in the evening (Figure 12) (e.g. Weidemann 1986). After sunset, they mostly descend into the more closed vegetation to spend the night.

On sunny days, it is mainly the male individuals that can be observed flying around in the habitat. Females fly less and invest more time in nectaring or just sitting in the vegetation. Therefore, one might get the impression that fewer females than males are present. However, this impression is misleading. Rearing of more than a hundred larvae randomly collected in the wild in Olk (southern Eifel, Rhineland-Palatinate, Germany) resulted in a nearly equal number of both sexes (Ashoff and Schmitt 2014).

The intensive flight activity within habitats leads one intuitively to overestimate the actual distance of translocations within and between habitats. Thus, a mark-release-recapture experiment with 2,211 marked butterflies in the Keuperscharren area south-west of Bitburg (southern Eifel, Rhineland-Palatinate, Germany) demonstrated that the exchange between habitat patches is much less than one would expect from the high flight activity of the butterflies. Only four individuals were detected to have moved between two patches separated by a distance of 600 m containing arable fields and intensive grassland with few flowers. Just one butterfly was found to have travelled a greater distance of 3.7 km (Schmitt et al. 2006). Similar experiments in Hampshire (southern Britain) showed that only 1 to 2% of the population exchanged between populations one to two km apart (Asher 2001). In another study in southern Britain, only 12 out of 1,797 marked butterflies moved between the three analysed habitats which were 350 to 1100 m distant from each other; however, five individuals even crossed a motorway while changing their habitat (Adey and Wilson 2010). In Luxembourg, none of 304 recaptured individuals (out of 2,085 marked ones) moved between three sites that were 4.2 to 11.2 km apart from each other (Thiel and Meyer 2007). For *P. gennargenti*, which might or might not be conspecific with *P. coridon* (see above), mark-release-recapture in four habitat patches with a maximum distance of 350 m between them showed that, with the exception of one rather small patch, emigration rates ranged from 3 to 11% (Casula et al. 2004).

In Britain, however, *P. coridon* adults were also found 10 to 20 km from known colonies, thus supporting the idea that a rather small (but ecologically highly important) proportion of the individ-

Figure 11. The imagoes of the chalk-hill blue visit flowers of different plant species for nectaring, here the cream scabious *Scabiosa ocholeuca* (left: Csákvár, Vértes mountains, western Hungary, 21.VII.2014) and a yellow-flowering Fabaceae (right: Luka nad Vahom, south-western Slovakia, 09.VIII.2014; note that the depicted individual is a member of the second generation of a bivoltine population). Photos: Thomas Schmitt.

uals is quite mobile (Asher et al. 2001). Similar findings are also known for Baden-Württemberg (Ebert and Rennwald 1991). One such particular case is described in more detail by Leverton (2014).

Even within a seemingly homogeneous habitat, the individuals did not mix randomly. Thus in the study performed in the Keuperscharren near Bitburg, one of the patches with a size of 6.7 ha was divided into two parts similar in size. No discontinuity in habitat separated these two subplots. Only 15 individuals out of 703 marked here could be recaptured. However, 13 of these were recaptured in the sector where they were first marked, and only two changed over to the respective other subplot (Schmitt et al. 2006). A quite similar finding was made in Luxembourg where only 12.5% of the recaptured individuals within one major calcareous grassland area were detected on a different part of this habitat (Thiel and Meyer 2007). This clearly demonstrates that individuals living in a larger habitat plot only use a relatively small fraction of the available habitat for their daily activities. Lörtscher et al. (1997) also supported this point of view by demonstrating in their mark-release-recapture experiment in Alpe di Poma (Ticino, Switzerland) that males on average moved 135 m between two capture events and did not mix randomly within one habitat. This was even more pronounced in females, which moved significantly less (on average 90 m) than males and changed between different parts of the habitat less frequently.

Further unpublished studies by the author in the nature reserve Badstube near Mimbach (Bliesgau, Saarland, Germany) in the year 1998 also support these data. The results of this study, based on more than 3,000 marked individuals, also showed that no random mixing took place on a seemingly homogeneous grassland area of some few hectares. Furthermore, a strip of deciduous forest within a deeply incised valley of approximately 100 m width reduced exchange to some very few individuals. However, it seems to be a common behavioural pattern of butterflies not to use larger continuous habitats entirely, but only a fraction of these, even if they do not exhibit territorial behaviour. A further example of this phenomenon is the lesser marbled fritillary *Brenthis ino*, studied in an assay in which all individuals were marked individually and positioned by a GPS device (Weyer and Schmitt 2013).

Despite these low exchange rates among habitats, mobility in general seems to be sufficient to counteract noticeable differentiation among populations, as was demonstrated by genetic analyses;

Figure 12. The imagoes of the chalk-hill blue often congregate in sleeping groups in the evening. Many individuals can assemble at exposed places, to utilise the last sunshine of the day. Gánt, Vértes mountains, western Hungary, 08.VIII.2014. Photo: Thomas Schmitt.

also see the rare long distance movements cited above (Ebert and Rennwald 1991, Asher et al. 2001). One study of allozyme polymorphisms at 20 different loci included 874 individuals from 22 populations sampled in Rhineland-Palatinate and the Saarland. The Bliesgau, a region with a remarkable density of viable populations (Schmitt 2002), had no significant genetic differentiation between the analysed populations. The amount of exchange in this region seems to be sufficient to completely hinder genetic differentiation between these populations. The calcareous regions of the western Saarland, the southern Eifel and the central Eifel, which all have a less dense network of populations than the Bliesgau, also had low rates of genetic differentiation among populations, and the mean of genetic variance between populations was less than 2% of the entire variance in all three of them. Hence, genetic differentiation between populations is apparently far from being critical in terms of conservation. The limited exchange rates seem to be sufficient to bolster against such a differentiation. Nevertheless, the larger populations expressed higher genetic diversity than the small ones (Schmitt and Seitz 2002a). Similar genetic findings with low differentiation between populations are also known for the Göttingen region. Here, it was demonstrated that the Leine valley with its intensive agriculture genetically separated the populations to the East and West of it (Krauss et al. 2004).

These results on population genetics are mostly supported by a classical ecological study from the Göttingen region which demonstrated that the population density of *P. coridon* is mainly dependent on the quantity of its larval host plant, in this case *H. comosa*, but not on the effect of habitat isolation and habitat quality (Krauss et al. 2005). Quite similar results were obtained by Rosin et al. (2011) southwest of Kraków (southern Poland); they showed that the best predictors for a potential habitat being occupied or not are its size and the percentage cover by the host plant, in this case *S. varia*. Hence, the chalk-hill blue is mostly dependent on the preservation of large habitats.

Another study from the Göttingen area yielded somewhat different results. No impact of the habitat area on the butterfly was found, but the importance of habitat connectivity was revealed. However, connectivity neither impacted the larval host plant occurrence nor the infection rate by parasitoids (Brückmann et al. 2011). This is also supported by population genetic data from this region showing that the expected heterozygosity of allozymes decreased with distance to other populations (Krauss et al. 2004).

Distribution and biogeography

The chalk-hill blue is mostly restricted to Europe (Kudrna et al. 2011), and the species is only found in a very restricted part of western Asia north of the Caspian Sea (Anikin et al. 1993, Lukhtanov and Lukhtanov 1994); it is missing in Turkey apart from a record of a single individual (Hesselbarth et al. 1995). The border of its south-western distribution is located in northern Spain (García-Barros et al. 2004). In the North-West, *P. coridon* is found up to south-eastern England (Emmet and Heath 1990; Asher et al. 2001). In Italy, the species can be found throughout the peninsula, but mostly in the Apennines at higher altitudes. Similarly, the species is widespread in the Balkan Peninsula where it is found as far south as the Peloponnese, but predominantly in mountain ranges (Pamperis 1997). The northern limit of distribution stretches along the northern margin of the German middle mountains (Bink 1992), and in the Netherlands it is only found in the extreme South of the country (Wynhoff et al. 1992). In eastern Germany, the chalk-hill blue is found along the Oder almost as far north as the Baltic Sea, which is reached in Poland (Buszko 1997, Buszko and Masłowski 2008). The species is completely missing in Scandinavia (Henriksen and Kreutzer 1982).

Studies of allozyme polymorphisms of several thousands of individuals of the chalk-hill blue allowed the reconstruction of the distribution dynamics over time. In this context, two major genetic lineages could be distinguished. A western lineage is found in Italy, France, the western and central Alps and major parts of Germany. An eastern lineage is distributed from the Balkan Peninsula, stretching over the Carpathian Basin to Brandenburg and Poland (Schmitt and Seitz 2001). Sequencing of mitochondrial genes also supports the differentiation into at least two major lineages, an eastern and a western one (Talavera et al. 2013). De Lesse (1969b) distinguished two major groups by their number of chromosomes, a western group with 87 or 88 chromosomes and an eastern group with 90 to 92 chromosomes. The distribution of these two groups almost perfectly matches the distribution of the two major allozyme groups, which also can be distinguished by morphological features (see above). Furthermore, it is only the eastern lineage which commonly uses *S. varia* as its larval host plant.

Along the contact zone between the lineages, intensive hybridisation was detected in some regions of the eastern Alps based on the allozyme data set. However, hybrid populations are rather rare north of the Alps, but for example were also found at two localities in Sachsen-Anhalt (Schmitt and Zimmermann 2012).

Within the western lineage, populations from the Pyrenees are well distinguished from all others. Furthermore, the populations from southern Germany (Baden-Württemberg to southern Thuringia) showed a genetic make-up that distinguished them as an individual group from all other populations (Schmitt et al. 2002). However, this group also includes populations from the Alps, as indicated by still unpublished data. Remarkable differences in genetic diversity can be observed between neighbouring regions in the western lineage, as for example between north-eastern France and western Germany (Schmitt et al. 2002). A continuous loss of genetic diversity from western Hungary to Brandenburg was observed for the eastern lineage. After performing a linear regression for the number of allozyme alleles for these populations, a highly significant correlation ($p < 0.001$) was obtained which explained 78% of the regional variation (Schmitt and Seitz 2002b).

These genetic patterns strongly support the existence of ice age refugia in Italy and in the Balkan Peninsula at least during the last glacial period. Here, these lineages evolved in allopatry. However, the process of evolution was not necessarily restricted to a single glacial period, but might have taken place during repeated periods of glacial isolation in these refugia. Ice age survival in these Mediterranean refugia has long been postulated (de Lattin 1949) and has been supported by numerous phylogeographic analyses since then (cf. Schmitt 2007). However, the differentiation of the populations in the Pyrenees as well as in southern Germany and parts of the Alps calls for additional refuge areas not resembling the pattern of the classical Mediterranean refuge areas. Additional glacial refugia therefore could have existed south of the Pyrenees and Alps. This assumption is also supported by still unpublished data based on sequences of two mitochondrial loci. Hence, the chalk-hill blue shows biogeographical traits of a species that is much more cold-tolerant than previously thought and which was thus able, at least additionally, to survive glacial periods in so called extra-Mediterranean refugia north of the classical Mediterranean refugia (cf. Schmitt and Varga 2012).

These genetic analyses also allow a relatively detailed reconstruction of the postglacial range expansion. The Adriato-Mediterranean lineage evolving in the Italian peninsula most probably had a north-western distribution limit during the last ice age located in north-western Italy or south-eastern France. Starting here, this lineage could colonise the regions northwards to Lorraine without genetic erosion, with the Rhône valley most probably representing an important expansion corridor. During the subsequent expansion into the western German region, remarkable genetic impoverishment has taken place. This might be explained by the, if compared to north-eastern France, considerably less favourable environmental conditions for this species in western Germany resulting in remarkable genetic erosions in the wake of the colonisation of this region (Schmitt et al. 2002).

During glacial conditions, the Ponto-Mediterranean lineage which survived the last ice age in the Balkan Peninsula most probably had its north-western distribution edge in the region of the northern Dalmatian Coast. Starting there, postglacial range expansion reached as far north as eastern Brandenburg. During a first advance, the species was able to colonise to the forelands of the eastern Alps. Here, the route of further expansion bifurcated. An eastern branch ran along the Hungarian middle mountains to eastern Slovakia. A western branch reached Moravia via the Porta Hungarica (lowland area between the north-eastern Alps and the south-western foothills of the Tatra Mountains). By a westwards advance, the species colonised the limestone regions of the Czech Republic. This advance was stopped by the mountain ranges between the Czech Republic and Germany, which were too cold and where soils were too acid to permit the survival of the species; on the other side of these mountains, all populations derive from the Adriato-Mediterranean

region (Schmitt and Zimmermann 2012). The further expansion out of Moravia northwards most probably first followed the river Vistula, and then in a westerly direction along the Torun-Eberswald glacial valley finally reaching eastern Brandenburg; most parts of the Odra region in Poland have rather few suitable habitats available for *P. coridon* so that this putative expansion corridor has to be considered less likely. The linear decline of the number of alleles from western Hungary to eastern Brandenburg implies a constant loss of genetic diversity in the Ponto-Mediterranean lineage during its postglacial range expansion (Schmitt and Seitz 2002b).

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Transfer of *Pygmaeotinea crisostomella* Amsel, 1957 from Tineidae to Psychidae and its taxonomic status (Lepidoptera)

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Abstract. *Pygmaeotinea* Amsel, 1957, syn. n. is transferred from Tineidae to Psychidae and regarded as congeneric with *Eumasia* Chrétien, 1904. The type species of *Pygmaeotinea* is combined with *Eumasia* as *Eumasia crisostomella* Amsel, 1957, comb. n. Adult male and female of this species are redescribed and illustrated for the first time. *Eumasia crisostomella* Amsel, 1957 is only known from the type locality in Portugal at Singeverga and one of three *Eumasia* species from Iberian Peninsula.

Zusammenfassung. *Pygmaeotinea* Amsel, 1957, syn. n. wird von den Tineidae zu den Psychidae transferriert und ist congenerisch mit *Eumasia* Chrétien, 1904. Die Typusart von *Pygmaeotinea* wird mit *Eumasia* als *Eumasia crisostomella* Amsel, 1957, comb. n. kombiniert. Adulte Männchen und Weibchen dieser Art werden erstmals abgebildet und die Beschreibung durch weitere Merkmale ergänzt. *Eumasia crisostomella* Amsel, 1957 ist nur von der Typenlokalität bekannt und eine von drei *Eumasia*-Arten der Iberischen Halbinsel.

Introduction

The monotypic *Pygmaeotinea* Amsel, 1957 was described within Tineidae. Its type-species, *P. crisostomella* Amsel, 1957 is only known from the type specimens and no further specimens have been reported thus far.

Amsel (1957) noted that the relationship of *Pygmaeotinea crisostomella* to other Tineidae is unknown. Karsholt and Razowski (1996) placed the genera *Eumasia* and *Pygmaeotinea* together with *Apterona* Millière, 1857 within Apteronini (Psychidae, Oiketicinae). Sauter and Hättenschwiler (1999) argued that this placement was done by the editors and does not reflect the opinion of the authors. They do not consider the first genus as belonging to Apteronini. Unfortunately, the original description does not allow us to judge the systematic placement of *Pygmaeotinea*, except that the information available suggests that it does not belong to Psychidae (Sauter and Hättenschwiler 1999).

Recently, *Pygmaeotinea* was re-transferred to Tineidae by Sobczyk (2011), but still provisionally. Even more recently, Gaedike (Bonn) found the type-series at the Staatliches Museum für Naturkunde Karlsruhe (SMNK). As an expert of Tineidae, after having examined the specimens, he came to the conclusion that they do not belong to Tineidae. Subsequently, he kindly arranged the loan of the type specimens to me.

Systematic part

Eumasia crisostomella Amsel, 1957, comb. n.

Figs 1–6

Examined material. Holotype ♂ "vi [1]950 / Singeverga" back cover (handwritten Amsel) "Portugal / coll. Monteiro", "GU 3199", red label "*Pygmaetinea crisostomella*", "coll. SMNK", genital slide with same information and additional "Holotypus"; Paratype 1 ♀ "Singeverga / vi.1953" back cover (handwritten Amsel) "Portugal / coll. Monteiro", genital preparation 3198, red label "Allotypus ♀, leg. H. Amsel", "coll. SMNK".

Citation of original description by Amsel.

(*Pygmaeotinea*)

Fühler des ♂ kurz bewimpert, bis etwa ½ Costa reichend. Kopfhaare abstehend. Vflg.-Geäder: Zelle offen, nur 3 Radialadern: r2+r3 und r3+r4 zu je einer Ader zusammengefallen; mit m1 und r4+r5 gestielt; m2 fehlend; ax ohne Wurzelschlinge. Hflg.-Geäder: rr und m1 gestielt, die Spitze umgreifend, m2 fehlend. Axillaradern stark reduziert. Genitalapparat des ♂: Uncus abgerundet, Gnathos fehlend, Vinculum (Saccus) zugespitzt, Valven in einen basalen und einen terminalen Teil gegliedert, ohne sonstige Strukturen.

(*crisostomella*)

Spw. 7 mm. Kopfhaare gelblich, Palpen bräunlich. Fühler des ♂ bis ½ Costa reichend, sehr kurz bewimpert, fast pubscent. Zwischen oberen Außenrand und der Fühlerwurzel ein großer quecksilberartiger Fleck. Vfgl. Gelblich. Ein großer bräunlicher Fleck am Innenrand bei ½, weitere Flecke im apikalen Flügelteil. Die Art ist durch den großen, fast viereckigen Fleck am Innenrand bei ½ gut charakterisiert. An der Costa stehen einige bräunliche Schuppen, im äußeren Drittel der Flügel häufen sich diese zu Flecken. Fransen graubraun. Hflg. Nur wenig schmaler als die Vflg. Fransen etwas länger als der Flügel breit ist. Beine ungeringelt. Genitalapparat des ♂: Uncus abgerundet, Gnathos fehlend. Vinculum ziemlich lang, zugespitzt. Valven aus zwei Teilen bestehend, einen äußeren, nicht strukturierten und einen inneren, der deutlich gegenüber dem Außenteil abgesetzt ist. Aedoeagus leicht gebogen, ziemlich lang, ohne Cornuti. Genitalpräparat 3199 (...) Einige Stücke wurden aus abgeflachten Säcken gezüchtet, die 7 mm lang mit Sandkörnchen besetzt sind.

Redescription *crisostomella*. Forewing length (with fringes) 3.5–4 mm, wingspan 7–8 mm. Labial palpi tripartite, median segment of double width and equal length as distal segment. Both segments covered with brown, ventrally directed hair-like scales. Antennal segments round, covered with short setae, dorsally with a semi-circular fan-like arrangement of broad, dark brown scales. The angle of this fan is 30–40° (see description of measurement by Hättenschwiler 1998). Forelegs with bristle brush (without epiphysis). Forewing scales long-oval, rounded distally, usually four- to six-pointed. Forewing ground colour yellowish, with a distinct dark brown spot at ½ of posterior margin and partly the anterior margin with some very narrow dark brown spots; distal third significantly spotted and converging partially to transverse lines. Fringe gray, hair-like, bi- or tricuspid. Hindwings uniformly dark gray. Male genitalia (genital preparation no. 3199 by Amsel): Total length 0.5 mm, very weakly sclerotized (perhaps an artifact due to excessive maceration). In ventral view, almost three times as long as wide. Valva extending beyond posterior margin of tegumen, weakly sclerotized distally with fine setae. Phallus 0.4 mm long, tubular, almost straight.

Figures 1–6. *Eumasia crisostomella* Amsel, 1957. **1.** ♂ Holotype, Portugal, Singeverga, vi. [1]950. **2.** Holotype genital preparation 3199. **3.** Detail antennae. **4.** Foreleg. **5.** ♀ Paratype ♀ same data, but vi.1953. **6.** ♀ Paratype genital preparation 3198. Scale bar: 1 mm (**1, 5**), 0.1 mm (**2, 3**), 0.5 mm (**4, 6**).

Female (differences to males). Antenna filiform, wingspan 8 mm. Wing pattern as in the male, but missing dark spots at the anterior margin of basal 2/3 of the forewings. Abdominal segment eight with dense, wavy hairs. Female genitalia (genital preparation no. 3198 by Amsel): 2.0 mm total length. Oviscapt with fine setae distally, supported by three pairs of apophyses. Posterior apophyses with a length of 1.9 mm, almost as long as the entire genitalia, anterior apophyses 0.85 mm long, forked distally, distal edge of antevaginal plate concave, covered with fine, distally directed spines. Ovipositor also with a third pair of 0.5-mm-long apophyses.

Diagnosis. *E. crisostomella* Amsel, 1957, comb. n. differs from *E. parietariella* (Heydenreich, 1851) from Central and South Europe and *Eumasia brunella* Hättenschwiler, 1998 from the Iberian Peninsula by the forewing pattern. Forewings of the latter two species are also covered with dark spots basally, but the dark spots of *E. crisostomella* are concentrated on distal third. On the basal 2/3 there are two or three small partial dark spots on the anterior margin. Most conspicuous is a large, almost square dark spot in the middle of the posterior margin. Hindwings of *E. parietariella* are light cream, of *E. brunella* brown and of *E. crisostomella* grey.

Remarks. The original description of *Pygmaeotinea* neither contains information about a differentiation from other genera nor why the description of a new genus was considered necessary. The venation (figure 5, Amsel 1957) and antennal and genital structures are clearly consistent with typical structures of *Eumasia*. A diagnosis for the genus is given by Hättenschwiler (1998). Particularly noteworthy is the scalation of the male antennae with a dorsally semi-circular fan-like arrangement of broad scales. Each antennal segment has a dorsal compartment of broader scales. Thus, *Pygmaeotinea* Amsel, 1957, syn. n. is identical to *Eumasia* Chrétien, 1904 and is synonymized here with it and its type species transferred to *Eumasia*, as *Eumasia crisostomella* Amsel, 1957, comb. n.

The label data do not completely match with information provided in the original description. Holotype ♂ denotes VI. [1]950 as date. There was no label on the pinned specimen that indicated it as the holotype. That information was only present on the genital slide belonging to this specimen and the slide number 3199 is present on both, the genitalia slide and on the pinned holotype specimen.

In the description the date for the female (allotype) is listed as vi.1950; however, the specimen label reads 'vi.1953'.

Acknowledgements

I thank Reinhard Gaedike (Bonn), who inspired the study, and Peter Hättenschwiler, who provided important information. I thank Robert Trusch and Michael Falkenberg (both State Museum of Natural History, Karlsruhe, Germany) for the loan of the type material of *E. crisostomella*. Last but not least, I thank Matthias Nuss (Senckenberg Museum of Zoology Dresden) for comments on the manuscript.

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A new species of *Micropterix* Hübner, 1825 from the Orobian Alps (Italy) (Lepidoptera, Micropterigidae)

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Abstract. *Micropterix gaudiella* Zeller & Huemer, **sp. n.** is described from the southern part of the Orobian Alps (Piedmont, Italy) and compared with its likely closest relatives *Micropterix isobasella* Staudinger, 1871 and *Micropterix stuebneri* Zeller, Werno & Kurz, 2013. The new species is well characterized by its wing pattern and colour and by structures of the male genitalia. The species status is furthermore supported by molecular data of the DNA barcode region. The distance to its nearest neighbour *Micropterix schaefferi* Heath, 1975 is 2.65%. *M. gaudiella* is the seventh species of the genus *Micropterix* Hübner, 1825 probably endemic to the Alps.

Introduction

The European fauna of *Micropterigidae* has recently gained increasing attention, reflected by faunistic reviews and several taxonomic papers (Corley 2007; Zeller-Lukashort et al. 2007; Thierry and Nel 2012; Zeller-Lukashort et al. 2013). The actual species inventory now seems well advanced as new species are rarely found and usually originate from insufficiently explored Mediterranean countries, with only two remarkable exceptions from the Central European Alps within the last four decades (Heath and Kaltenbach 1984; Kurz et al. 2004). Sampling of an unidentified *Micropterix* in the Italian Alps (Pizzo Arero, Orobian Alps, Piedmont, Italy) by PH and colleagues in June and July 2013 and 2014 thus came as a surprise. Although only few females were available in first hand, phenotypic appearance and the DNA barcode did not match any hitherto described species from the region. It was therefore decided to search for additional samples and we finally succeeded in collecting a large series of the species in summer 2014 including the male sex. Subsequent analysis of male genitalic characters supported the recognition of a new species, which is described here.

Material and methods

Our study is based on almost 277 specimens of the new *Micropterix* species and uncounted material of all European congeners. The type material is only partially set whereas several samples were only spread and dried immediately after collecting to ensure sufficient quality of DNA samples. Genitalia preparations followed standard techniques used for the family Micropterigidae (Zeller-Lukashort et al. 2007). Photographs of the adults were taken with an Olympus SZX 10 binocular microscope and an Olympus E-3 digital camera and developed using the software HELICON FOCUS 4.3, ADOBE PHOTOSHOP CS4 and LIGHTROOM 2.3. DNA barcode sequences are based on a 658 base-pair long segment of the mitochondrial COI gene (cytochrome c oxidase 1). DNA samples (dried legs) were prepared according to the prescribed standards (deWaard et al. 2008). Present authors and associated colleagues tried to obtain DNA barcodes of the majority of European Micropterigidae. Legs from 379 specimens belonging to 57 species of *Micropterix* have so far been processed at the Canadian Centre for DNA Barcoding (CCDB, Biodiversity Institute of Ontario, University of Guelph) to obtain DNA barcodes (BOLD 2015) using the standard high-throughput protocol described in Ivanova et al. (2006) and deWaard et al. (2008). DNA sequencing resulted in a barcode fragment of 658 bp for a total of 149 specimens and 29 species (BOLD 2015), partially published earlier by Lees et al. (2010). Ninety-one sequences belonging to 25 species are treated in this study and enable delimitation of the new species. Details of successfully sequenced voucher specimens including complete voucher data and images can be accessed in the Barcode of Life Data Systems: public dataset "Lepidoptera of the Alps - Micropterix [DS-LEALMIC]" (BOLD 2015; Ratnasingham and Hebert 2007). Degrees of intra- and interspecific variation in the DNA barcode fragment were calculated under Kimura 2-parameter (K2P) model of nucleotide substitution using analytical tools in BOLD Systems v3.0 (BOLD 2015). A neighbour-joining tree of DNA barcode data of European taxa was constructed using MEGA 5 (Tamura et al. 2011) under the K2P model for nucleotide substitutions.

The morphology of the new species is compared with similar species from the Alps and also from other regions of Europe (Kurz and Kurz 2015). We consequently build on the important identification treatments by Heath (1987), Kozlov (1989, 1990a, b) and Zeller-Lukashort et al. (2007). For more information about collection sites, preparation techniques and data archive of *Micropterix* spp. see Zeller-Lukashort et al. (2007).

Abbreviations of private and institutional collections:

MBCG Italy, Bergamo, Museo di Scienze Naturali "Enrico Caffi";
RCTM Research Collection Toni Mayr, Feldkirch, Austria;
RCCZ Research Collection Christof Zeller, Thalgau, Austria;
RCNP Research Collection Norbert Pöll, Bad Ischl, Austria;
RCSO Research Collection Siegfried Ortner, Bad Ischl, Austria;
TLMF Tiroler Landesmuseum Ferdinandeum, Innsbruck, Austria.

Results

Checklist of European *Micropterix*

The species listed below occur within Europe (Karsholt 2015, Kurz and Kurz 2015), presented in an order considered to reflect morphological relationships among the species as suggested by Kurz

et al. (2015). Many of the morphological characters of *Micropterix* have been found to be more or less similar in smaller or greater groups of species and it has been assumed that similarities or synapomorphies of the male genitalia indicate a closer relationship. Based on a specific character matrix several characters have been selected and attributed as plesiomorphic or apomorphic (but see Kurz et al. 2015).

Micropterix mansuetella Zeller, 1844
Micropterix amsella Heath, 1975
Micropterix calthella (Linnaeus, 1761)
Micropterix isobasella Staudinger, 1871
Micropterix stuebneri Zeller, Werno & Kurz, 2013
Micropterix gaudiella sp. n.
Micropterix granatensis Heath, 1981
Micropterix aglaella (Duponchel, 1838)
Micropterix wockei Staudinger, 1870
Micropterix aureatella (Scopoli, 1763)
Micropterix herminiella Corley, 2007
Micropterix aruncella (Scopoli, 1763)
Micropterix corcyrella Walsingham, 1919
Micropterix lakoniensis Heath, 1985
Micropterix kardamylensis Rebel, 1903
Micropterix igaloensis Amsel, 1951
Micropterix cassinella Kurz, Kurz & Zeller, 2010
Micropterix klimeschi Heath, 1973
Micropterix completella Staudinger, 1871
Micropterix tunbergella (Fabricius, 1787)
Micropterix sicanella Zeller, 1847
Micropterix cypriensis Heath, 1985
Micropterix aureoviridella (Höfner, 1898)
Micropterix maschukella Alphéraky, 1876
Micropterix facetella Zeller, 1850
Micropterix jeanneli Viette, 1949
Micropterix renatae Kurz, Kurz & Zeller-Lukashort, 1997
Micropterix minimella Heath, 1973
Micropterix italica Heath, 1981
Micropterix erctella Walsingham, 1919
Micropterix uxoria Walsingham, 1919
Micropterix paykullella (Fabricius, 1794)
Micropterix garganoensis Heath, 1960
Micropterix imperfectella Staudinger, 1859
Micropterix tuscaniensis Heath, 1960
Micropterix hartigi Heath, 1981
Micropterix allionella (Fabricius, 1794)
Micropterix trifasciella Heath, 1965

Micropterix rothenbachii Frey, 1856
Micropterix huemeri Kurz, Kurz & Zeller-Lukashort, 2004
Micropterix ibericella Caradja, 1920
Micropterix zangheriella Heath, 1963
Micropterix schaefferi Heath, 1975
Micropterix emiliensis Viette, 1950
Micropterix osthelderi Heath, 1975
Micropterix trinakriella Kurz, Zeller-Lukashort & Kurz, 1997
Micropterix vulturensis Heath, 1981
Micropterix rablensis Zeller, 1868
Micropterix myrtetella Zeller, 1850
Micropterix croatica Heath & Kaltenbach, 1984
Micropterix fenestrellensis Heath & Kaltenbach, 1984

Taxonomic part

Micropterix gaudiella Zeller & Huemer, sp. n.

http://zoobank.org/4AA658ED-DED7-46A7-908E-231CBC52A8A7

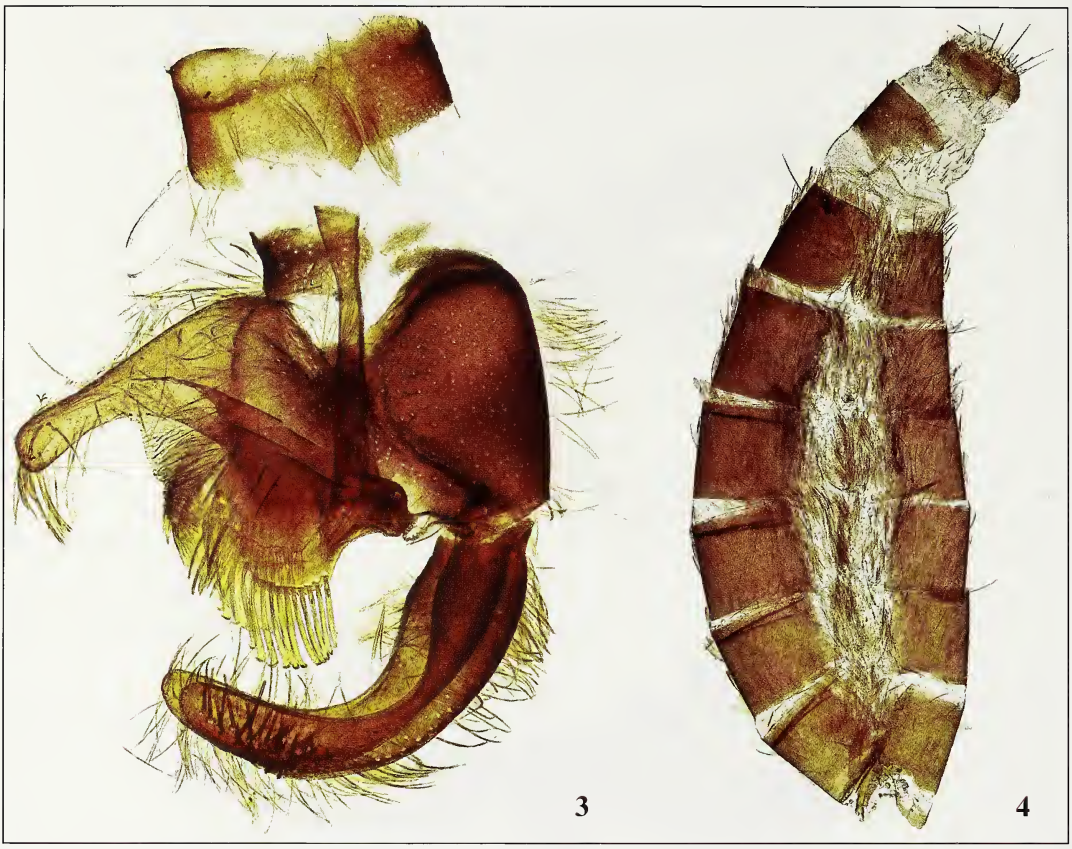
Material. Holotype ♂: Italia sept., Bergamo, Alpi Orobie Rifugio Ca d´Arera 1600 m 9°47,8'E, 45°55,07'N 25.vi.2014, leg. Huemer TLMF 2014-006 (TLMF), label with identification numbers CZ-Z30577, label "DNA BARCODE TLMF Lep14851" and red label "HOLOTYPE of *Micropterix gaudiella* Zeller & Huemer". – Paratypes: 4 ♀, same locality as holotype, but 16.vii.2013, leg. Massaro M. (MBCG), labels with identification numbers CZ-Z30771, CZ-Z30774–CZ-Z30776; 3 ♂, 2♀, same locality as holotype, but 17.vii.2014, leg. Siegfried Ortner (RCSO), labels with identification numbers CZ-Z29417, CZ-Z29459–CZ-Z29462; 40 ♂, 22 ♀, same data as holotype, but leg. Norbert Pöll (RCNP), labels with identification numbers CZ-Z29463–CZ-Z29524; 69 ♂, 26 ♀, same data as holotype, but leg. Mayr Toni (RCTM), labels with identification numbers CZ-Z29360–CZ-Z29369, CZ-Z29371–CZ-Z29416, CZ-Z29418–CZ-Z29445, CZ-Z29446 and AP: MK-1072, CZ-Z29448–CZ-Z29457; 76 ♂, 15 ♀, same data as holotype (TLMF), labels with identification numbers CZ-Z29330–CZ-Z29347, CZ-Z30561–CZ-Z30576, CZ-Z30578–CZ-Z30580, CZ-Z30582–CZ-Z30623, CZ-Z30625–CZ-Z30631, CZ-Z30633–CZ-Z30634, CZ-Z30636–CZ-Z30638; 16 ♂, same locality as holotype, but 23.vi.2014, labels with identification numbers CZ-Z29314–CZ-Z29327, CZ-Z29328 and AP-Nr 1/2014, CZ-Z29329; 1 ♂, same data as holotype (TMLF), label with identification number CZ-Z30581, label "DNA BARCODING TMLF Lep14853"; 1 ♀, same data as holotype (TMLF), label with identification number CZ-Z30624, label "DNA BARCODING TMLF Lep14852"; 1 ♀, same locality as holotype, but 25.vi.2013, leg. Huemer (TLMF), label with identification number CZ-Z29359, label "DNA BARCODING TMLF Lep09987". All 276 paratypes bear red label "PARATYPE of *Micropterix gaudiella* Zeller & Huemer".

Description. Adult (Figs 1, 2). Forewing length 3.5–3.9 mm (♂, n=206), 4.0–4.4 mm (♀, n=71). Head black-brown; vestiture of hair-like scales on the head, yellow to dirty yellow; antennae dark brown, respectively 3/4 (♂) and 1/2 (♀) of forewing length; thorax and tegulae violet with golden reflection; forewing dull bluish with conspicuously broad and mostly bronzy golden markings: a trapeziform fascia at 1/4, at 1/2 a moderately broad straight fascia across the whole wing width, inwardly oblique, at 3/4 a broad, variably shaped, inwardly convex fascia; fringe bronzy golden, basally bluish violet; hindwing bronzy golden, apically tinged purplish; fringe bronzy golden; legs and abdomen brown, golden shining.

Figures 1–2: Adults of *M. gaudiella* sp. n. **1**: ♂. **2**:♀.

There is some variation in the ground coloration from dull bluish to purple-violet. Sometimes there is also a small spot on the costa at 3/5. The wing pattern differs between the sexes only a little in the broadness of the fasciae, as is typical for the genus.

♂ Genitalia (Fig. 3). Uncus long, slender, with a broad rounded tip; a paired association of hair-like setae ventrally beyond the uncus; accessory claspers moderately long, nearly keel-shaped; along distal margin, a row of about 10–12 moderately long distally hook-like modified thickened setae oriented in slightly ventral direction; at inner surface proximally another irregular row of five or six shorter, finer setae; valvae moderately long, stout, distal third enlarged and strongly bent dorsally, constricted at the point of inflection; on the inner surface of the valvae a group of shorter



Figures 3–4: Genitalia of *M. gaudiella* sp. n.. **3**: ♂. **4**. ♀.

setae postbasally; on the inner surface of the lower margin two to three irregular rows of shorter spinous setae and some longer setae on the distal fourth part.

♀ Genitalia (Fig. 4). Tergite IX missing; sternite IX reduced, constricted medially, with strongly fringed lateral margins, without diagnostic features. Terminal papillae with two sclerotized plates forming an undiagnostic band; receptaculum seminis long and slender, constricted in the first third, with transverse striation typical for the genus.

Diagnosis. *M. trifasciella* from Piedmont (Italy) shows somewhat similar but conspicuously narrower fasciae and differs in the ground colour. *M. rablensis* from Friuli (Italy), Carinthia (Austria) and western Slovenia shows a somewhat similar wing pattern but is predominantly smaller and differs in the reddish bronzy golden to purple ground coloration of the forewings. *M. completella*, endemic to Sardinia and Corsica (Thierry and Nel 2012), has usually lighter purple-violet forewings with comparably broad fasciae and differs in the shape of the outer fascia. From all these mentioned species, the new species is furthermore clearly separated by its male genitalia, e.g. by the distinct shape of uncus and accessory claspers as well as by the orientation and form of the 10–12 long setae on the accessory claspers (Kurz and Kurz 2015). In the male genitalia, the new species closely resembles *M. isobasella* from Valais (Switzerland) (Fig. 5) and the recently described *M. stuebneri* from Sierra Nevada (Spain), being distinguished from *M. isobasella* mainly

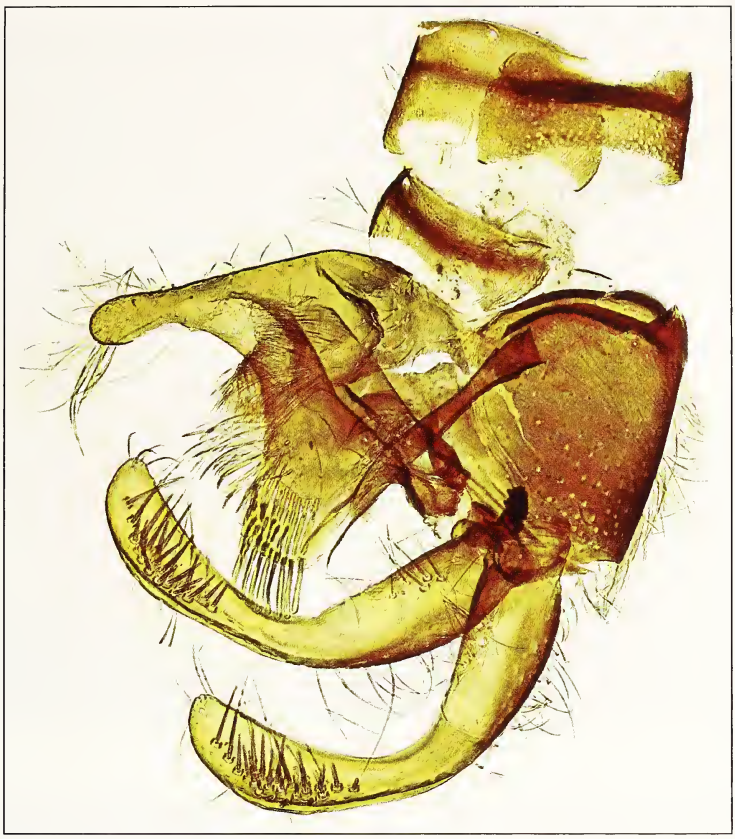


Figure 5. Male genitalia of *M. isobasella*.

by its longer uncus and the partly hook-like modified thickened setae at the rounded distal margin of the accessory claspers and from *M. stuebneri* mainly by its distinctly shorter and smaller accessory claspers (Zeller-Lukashort et al. 2013). *M. isobasella* can also easily be distinguished by its unicolorous golden forewings without any significant markings. In the female genitalia the new species differs from *M. rablensis* by the shape of sternite IX, from *M. trifasciella* and *M. completella* by its strongly fringed lateral margins of sternite IX. There are no differences in the female genitalia between *M. isobasella* and the new species.

Based on morphological characters (Kurz et al. 2015), the new species is considered to belong to a species-complex together with *M. calthella*, *M. isobasella* and the recently described *M. stuebneri*.

Molecular data. The intraspecific divergence of the barcode region of *M. gaudiella* sp. n. is moderate with a mean distance of 0.46% and a maximum distance of 0.77% (n=4) (Tab. 1). The minimum distance to the nearest neighbour *M. schaefferi* on the contrary is much higher with 2.65% (mean dist. 3.18%, max. dist. 3.76%; n=9). The minimum distance to the morphologically closest *M. isobasella* is 3.67% (mean dist. 3.85%, max. dist. 4.18%; n=1) and to *M. stuebneri* 4.73% (mean dist. 4.99%, max. dist. 5.22%; n=1).

Distribution. The new species is only known from the mountain Pizzo Arero (Alpi Orobie, Piedmont, Italy) from an elevation of about 1600 m.

Table 1. Intraspecific distance and interspecific divergence to the nearest neighbour in the genus *Micropterix*, based on 25 European species. Source: DNA Barcode data from BOLD (Barcode of Life Database, cf. Ratnasingham and Hebert 2007).

Species	Mean Intra	Max intra	Nearest neighbour	Nearest species	Distance NN
Micropterix allionella	0.18	0.46	LEATE038-13	*Micropterix rothenbachii*	1.86
Micropterix amsella	N/A	N/A	LEFIG229-10	*Micropterix mansuetella*	5.35
Micropterix aruncella	1.7	2.99	PHLAG682-12	*Micropterix schaefferi*	2.97
Micropterix aureatella	0.39	0.77	PHLAG682-12	*Micropterix schaefferi*	2.74
Micropterix aureoviridella	0.21	0.46	PHLAG682-12	*Micropterix schaefferi*	2.74
Micropterix calthella	0.18	0.46	PHLAG682-12	*Micropterix schaefferi*	2.74
Micropterix erctella	N/A	N/A	PHLAG682-12	*Micropterix schaefferi*	2.05
Micropterix facetella	1.84	1.84	PHLAG682-12	*Micropterix schaefferi*	2.51
Micropterix gaudiella	0.46	0.77	PHLAD506-11	*Micropterix schaefferi*	2.65
Micropterix hartigi	N/A	N/A	PHLAG682-12	*Micropterix schaefferi*	2.74
Micropterix igaloensis	N/A	N/A	LEATE039-13	*Micropterix schaefferi*	2.9
Micropterix isobasella	N/A	N/A	PHLAG682-12	*Micropterix schaefferi*	3.01
Micropterix jeanneli	N/A	N/A	PHLAG682-12	*Micropterix schaefferi*	4.15
Micropterix klimeschi	N/A	N/A	PHLAE527-11	*Micropterix aruncella*	3.79
Micropterix mansuetella	N/A	N/A	LTOLB478-09	*Micropterix calthella*	4.35
Micropterix myrtetella	N/A	N/A	PHLAG682-12	*Micropterix schaefferi*	1.82
Micropterix osthelderi	0	0	PHLAG682-12	*Micropterix schaefferi*	3.21
Micropterix rablensis	N/A	N/A	PHLAG682-12	*Micropterix schaefferi*	2.62
Micropterix rothenbachii	0.21	0.32	PHLAG787-12	*Micropterix allionella*	1.86
Micropterix schaefferi	0.41	1.12	MICOW166-09	*Micropterix vulturensis*	0.9
Micropterix sicanella	N/A	N/A	PHLAG682-12	*Micropterix schaefferi*	3.44
Micropterix stuebneri	N/A	N/A	PHLAG682-12	*Micropterix schaefferi*	2.28
Micropterix tunbergella	0.05	0.16	PHLAG682-12	*Micropterix schaefferi*	3.45
Micropterix vulturensis	N/A	N/A	PHLAG682-12	*Micropterix schaefferi*	0.9
Micropterix wockei	N/A	N/A	LEATE039-13	*Micropterix schaefferi*	3.89

Life history. The early stages are unknown. The new species was observed from the end of June to mid-July near the border of a montane-subalpine beech forest with tall herbaceous vegetation and bushes (Figs 6, 7), congregating on *Rosa* sp. feeding on its pollen. Together with the new species, *M. aruncella* (Scopoli, 1763) was recognized on flowers of *Rosa* sp. too (Fig. 8). At the same locality *M. rothenbachii* Frey, 1856 was also found. Several specimens of the new species were swept from flowers of *Helianthemum* spp. in adjacent subalpine grassland. The habitat is southern exposed slopes on limestone.

Etymology. It was a great pleasure to find this unexpected new species from the Italian Alps. Therefore the new species is called "*gaudiella*", derived from the Latin word "gaudium", which means "fun, pleasure, happiness".

Remark. The labels used by PH, Melania Massaro, Toni Mayr, Norbert Pöll and Siegfried Ortner differ in the usage of local names of the type locality but all refer to the same spot centred on 9°47,8'E; 45°55,07'N (DDM). According to Melania Massaro there are additional specimens collected at the type locality and deposited in MBCG, which are not examined and therefore not included in the type series.

Figure 6. Biotope of *M. gaudiella* and the lucky collectors Marlies Mayr, Toni Mayr and Norbert Pöll.

Figure 7. *M. gaudiella* sp. n., resting on a flower of *Rosa* sp..

Figure 8. *M. aruncella* and *M. gaudiella* sp. n. feeding on *Rosa* sp.

Molecular analysis

Sequencing of European species of *Micropterix* resulted in barcode fragments for 61 specimens, plus 30 unpublished or public records from external projects (e.g. Barcoding Fauna Bavarica and Finnish Barcode of Life), covering altogether 25 species, supplementing data of extra-European species that have been published by Lees et al. (2010). 74 full barcode sequences of 658 bp, 13 sequences longer than 600 bp and four sequences of ca. 400 bp were included in the analysis. The smaller fragments were single sequence only (*M. amsella*, *M. mansuetella*, and *M. rablensis*).

Barcode variation is insufficiently known for a considerable portion of species due to lack of successfully sequenced samples (Table 1). Intraspecific distance is low and ranges from 0% to 2.99% (mean 0.92%) but may include cases of overlooked cryptic diversity in species with high divergence (i.e. *M. aruncella*, *M. facetella*). Interspecific divergence for the whole sample is moderately high with mean divergence of 4.77% and maximum of 8.91%, and a mean and maximum distance to the nearest neighbour of 2.84% and 5.35% respectively. The divergence is <1% only in one species pair (*M. schaefferi* and *M. vulturensis*) (Table 1, Fig. 9).

Discussion

Alpha-taxonomy of European *Micropterix* seems quite well established with relatively few taxa described during the last decades, so it is striking to find a new species in Central Europe. By contrast, the distribution of the majority of *Micropterix* species is only moderately well documented with few

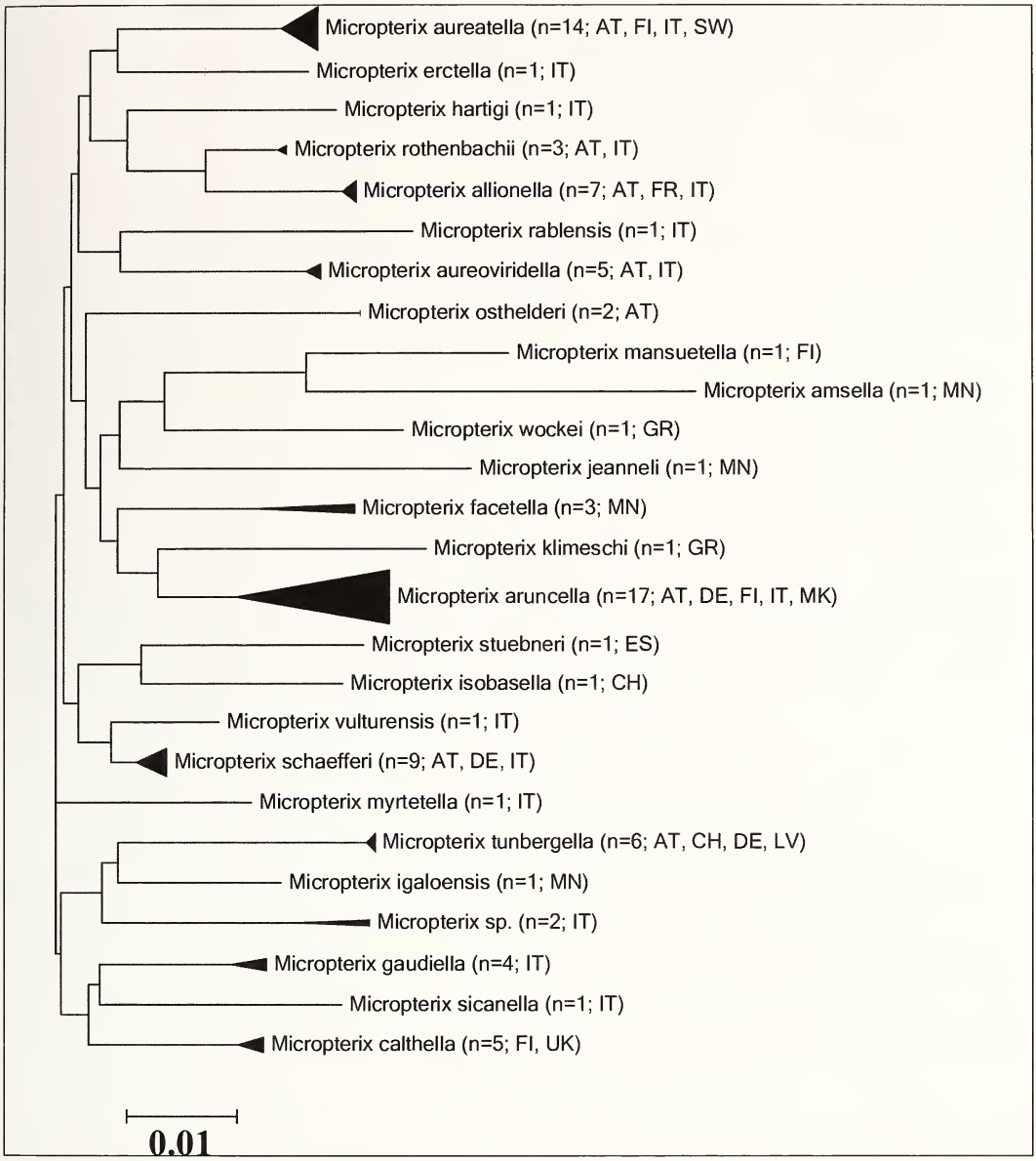


Figure 9. Neighbour-joining tree (Kimura 2-parameter, built with MEGA 5; cf. Tamura et al. 2011). Note: the scale bar only applies to internal branches between species. The width of the triangles represents the sample size, and the depth the relative genetic variation within the cluster (2× scale bar). Source: DNA Barcode data from BOLD (Barcode of Life Database, cf. Ratnasingham and Hebert 2007).

faunistic studies, particularly as concerns the Mediterranean region. Despite this shortcoming, it already appears evident from published sources that *Micropterix* exhibits remarkable levels of narrow range endemicity. Indeed about three-quarters of the European taxa can be clustered into the following disjunct endemism groups (Karsholt 2015; Zeller-Lukashort et al. 2013; Kurz and Kurz 2015).

Apennines: 9 out of 20 species are endemic.
Alps: 7 out of 19 species are endemic.
Balkan Peninsula: 9 out of 17 species are endemic.
Iberian Peninsula: 5 out of 8 species are endemic.
Mediterranean islands: 8 species are endemic.
Black Sea area: 1 species is endemic.

Also, only 12 species (about one-quarter of European *Micropterix*) are widely distributed across Europe, and only one species (*M. aureatella*) reaches Japan (Kurz and Kurz 2015). *M. aruncella*, *M. aureatella*, *M. calthella*, *M. mansuetella* and *M. tunbergella* are known to range across from the mainland to geographically well separated islands (although a few micropterigids occur within an island group, such as *Sabatinca* occurring in both North and South Island of New Zealand: Gibbs 1983; Gibbs and Lees 2014; see also Imada et al. 2011). Endemism in the Lepidoptera fauna of the Alps in general and *Micropterix* in particular probably largely results from the history of glaciation, which is reflected in nine biogeographic zones defined by vegetation (Ozenda 1988). These zones have been partially considered as areas of endemism for Lepidoptera (Huemer, 1988). The majority of endemic *Micropterix* occur in the Western Alps and are restricted to the so-called "Inner Alps" (i.e. *M. isobasella*, *M. paykullella*, *M. trifasciella* and *M. fenestrellensis*) whereas *M. huemeri* is restricted to the adjacent "Pre-Ligurian" biogeographic zone. However, the highest diversity of endemic Lepidoptera in general is present in the so-called "Gardesan-Illyrian zone" of the south-eastern Alps which is defined by limestone massifs at the southern border of the Alps reaching from Lake Como in the west to the Karawanks in the east. More than 30 endemic Lepidoptera species are known from this area (Huemer 1998). *M. gaudiella* is the first species of the genus *Micropterix* probably endemic to this zone, while a further species, *M. rablensis*, is more widespread and also occurs in the northern part of the Eastern Alps. The Orobian Alps in particular seem to have attracted insufficient attention among lepidopterists so far and still host a considerable number of cryptic species belonging to various groups. A new species of *Kessleria* (Huemer & Mutanen, 2015) and a distinct subspecies of *Colostygia* (Huemer & Mayr, 2015) are striking examples. It seems not unlikely that further undescribed endemic *Micropterix* may be found in other remote and under-collected areas of Europe, e.g. on the Balkan and Iberian Peninsulas. Outside Europe, despite the efforts of John Heath, there are probably a number of undetected species in North Africa, while the Himalayas as far as China are virtually unexplored for the genus (but see Lees et al. 2010).

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Coleophora gryphipennella (Hübner, 1796) (Lepidoptera, Coleophoridae) on *Fragaria vesca* L. (Rosaceae), a novel host, in the coastal dunes of The Netherlands

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Abstract. During regular surveys of Lepidoptera in the coastal dune North Holland Dune Reserve, we observed larval cases and feeding traces typical for Coleophoridae on wild strawberry (*Fragaria vesca* L., Rosaceae). The spatulate or pistol shape of the cases excluded *Coleophora violacea* (Ström, 1783) and *C. potentillae* Elisha, 1885. According to the literature, *C. albicostella* (Duponchel, 1842), very rare in The Netherlands, was the only *Coleophora* species known to create spatulate cases on this host. We collected larval cases for DNA analysis on the larvae and for rearing, which revealed that none of the collected larvae belong to the Coleophoridae previously recorded feeding on this host, but a mixture of three other *Coleophora* species. We found that early instar larvae of *C. lutipennella* (Zeller, 1838) and *C. flavipennella* (Duponchel, 1843), normally feeding on oaks (*Quercus* spp., Fagaceae) only, may be found feeding on *F. vesca* in the fall. We also found that *C. gryphipennella* (Hübner, 1796), abundant on Rose (*Rosa* spp., Rosaceae) in the coastal dunes of The Netherlands, regularly feeds on *F. vesca* and rearing experiments proved that it can complete its larval stage on *F. vesca*. We therefore conclude that *Fragaria* is a new host genus for *C. gryphipennella*. After reviewing all the *C. albicostella* records from The Netherlands, we conclude that it is a very rare species, likely restricted to the southernmost provinces. None of the confirmed records are from reared specimens. The host range of *C. albicostella* in literature is possibly overestimated and may not even include *Fragaria*.

Introduction

The coastal dunes of the province North Holland constitute a region rich in Lepidoptera. The North Holland Dune Reserve, a 53 km^2 dune area roughly between the cities of Wijk aan Zee and Bergen, is a particularly rich area. Here, 1,449 species of moths (macro- and microlepidoptera) have been recorded in the Dutch national observation database "NOCTUA" (Ellis 2015a), 1,353 of which were recorded from year 2000 onwards. In total in this database approximately 2,400 different species of Lepidoptera have been recorded for The Netherlands. The North Holland Dune Reserve is protected by Natura 2000 laws and is managed by the private water company PWN. The first author is one of the volunteers who inventory Lepidoptera in this reserve. During day-time collecting, he encountered larval cases and feeding traces typical for Coleophoridae on wild strawberry (*Fragaria vesca* L., Rosaceae).

Many Coleophoridae are leaf miners as larvae, although, unlike most other leafmining groups, they can arbitrarily change their host during the larval life stage and do not stay in the leafmines continuously. The larvae build a portable case that is constructed from silk and plant tissue, usually the epidermal layers of a plant leaf (Emmet et al. 1996). The cases often have a distinctive shape and several types of cases have been designated by different authors and are included in identification keys (Hering 1951; Toll 1953; 1962; Patzak 1974; Emmet et al. 1996). However, the shape of the case can change significantly between early and later instars. Furthermore, some species shift between leaf mining to seed mining or flower or flower-bud mining, for example *Coleophora salinella* Stainton, 1859, *C. tricolor* Walsingham, 1899, and *C. bernoulliella* (Goeze, 1783) (Emmet et al. 1996). Nonetheless, most species are monophagous and the host plant is an important character for identification.

Three species of Coleophoridae were known to feed on *Fragaria* in Europe according to the literature (Hering 1957; Klimesch 1958). Two of these create lobe type cases, viz. *Coleophora violacea* (Ström, 1783) and *C. potentillae* Elisha, 1885 and can easily be recognized (Emmet et al. 1996; Ellis 2015b). The third species that had been reported to feed on *Fragaria* is *C. albicostella* (Duponchel, 1842), which creates a spatulate case, a more common case type amongst Coleophoridae. *C. albicostella* is a very rare species in The Netherlands with about a dozen registered observations or collected specimens since 1880 (Küchlein and Donner 1993; Willem Ellis, pers. comm.; RMNH and ZMA collections [Naturalis Biodiversity Center, Leiden, The Netherlands]). To find out which species we found feeding on *Fragaria* with spatulate or pistol shaped cases, we photographed, collected, and reared them and analysed their DNA.

Material and methods

Localities

The North Holland Dune Reserve stretches roughly from 52.487°N, 4.590°E to 52.682°N, 4.691°E and has an area of roughly 53 km^2. We did most of our observations in the area just south of the village Bergen aan Zee at two main localities. One is a small patch of woodland surrounded by an open dune area relatively close to the inland border of the North Holland Dune Reserve, with English Oak (*Quercus robur* L., Fagaceae) as the main tree species and *F. vesca* dominant in the herb layer, further indicated as 'L1_Oak'. The other locality is a small patch of woodland surrounded by an open dune area relatively close to the North Sea with Birch (*Betula* sp., Betulaceae) as the main tree species and again *F. vesca* dominant in the herb layer, further indicated as 'L2_Birch'. In addition, we carried out some observations in the surrounding area. An overview of all localities and dates is provided in Table 1. JvR took the photographs, with a Canon EOS 7D camera with a Canon EF 100mm f/2.8L Macro IS USM lens, except for the photographs in figures 15 and 16, which were taken with a Nikon D80 camera with a Micro-Nikkor AF 60mm f/2.8 D lens.

Rearing

On 29.x.2013 and 19.xi.2013, we collected spatulate cases on *Fragaria vesca* at the L2_Birch locality. We kept the collected larval cases in a small transparent plastic jar and put them in a garden shed to hibernate, along with small pieces of the host plant. In March 2014 we transferred the cases to fresh *Fragaria* leaves in the garden. We first observed fresh feeding traces on 11.iv.2014, the active larvae still with spatulate cases. On 05.v.2014 we observed that the most active larva had stopped feeding and that the case had moved to the petiole of the leaf it had been feeding on. The case now

Table 1. Localities of the *Coleophora* observations of this study in chronological order.

Date	GPS coordinates	Loc. name	Case type*	Host	Used for
20.v.2011	N52.638, E4.650	L1_Oak	Spatulate	*Fragaria vesca*	
24.v.2011	N52.638, E4.650	L1_Oak	Spatulate	*Fragaria vesca*	
11.x.2011	N52.644, E4.633	L2_Birch	Spatulate	*Fragaria vesca*	
20.ix.2012	N52.640, E4.653		Pistol	*Fragaria vesca*	
02.x.2012	N52.644, E4.633		Spatulate	*Fragaria vesca* and *Rosa* sp.	
19.x.2013	N52.644, E4.633	L2_Birch	Spatulate	*Fragaria vesca* and *Rosa* sp.	DNA analysis
29.x.2013	N52.638, E4.650	L1_Oak	Spatulate and pistol	*Fragaria vesca*	DNA analysis
29.x.2013	N52.639, E4.650	L1_Oak	Spatulate	*Rosa* sp.	DNA analysis
29.x.2013	N52.641, E4.656		Spatulate	*Rosa* sp.	DNA analysis
19.xi.2013	N52.643, E4.633	L2_Birch	Spatulate	*Fragaria vesca*	Rearing
07.v.2014	N52.637, E4.649	L1_Oak	Spatulate	*Fragaria vesca*	Rearing

*The case types following Emmet et al. (1996)

had a trivalved appearance. We transferred the case into a small plastic jar and kept it indoors until emergence. We found the second case lying on a leaf rather than being attached to the underside and we assumed that the larva had died. We obtained another rearing result from a still fresh spatulate case on *F. vesca* on 07.v.2014 in the dunes near Egmond (GPS coordinates 52.637°N, 4.649°E) by collecting the case together with fresh leaves that were taken indoors until emergence.

DNA barcoding

We selected ten specimens from different localities and hosts for DNA analysis, see Table 2. We pulled the larvae from their case with forceps, damaging the case as little as possible. The cases are stored as vouchers in the RMNH collection. For DNA analysis we used the mitochondrial COI-barcode gene region (Hebert et al. 2003). DNA extraction and PCR amplification followed the methods described in van Nieukerken et al. (2012). We added the collecting and sequence data of the specimens to the Barcode of Life Datasystems (BOLD; Ratnashingham and Hebert 2007), under their unique RMNH registration number as sample ID. Sufficient reference material of all potential *Coleophora* species that feed on *Fragaria* was available in BOLD and we made identifications of the larvae by examining the distance to the nearest neighbour. There was a 100% match for most samples, and also the monophyly criterion was met, when we evaluated whether our sequence fitted within a monophyletic DNA barcode species cluster.

Abbreviations

RMNH Rijks Museum voor Natuurlijke Historie collection, housed at Naturalis Biodiversity Center, Leiden, The Netherlands.

ZMA Zoölogisch Museum Amsterdam collection, housed at Naturalis Biodiversity Center, Leiden, The Netherlands.

Results

Field observations

In the spring of 2011 at locality 'L1_Oak', during an intensive search for *Tinagma perdicella* Zeller, 1839 (Douglasiidae), which flies during daytime and can be found close to *Fragaria*, JvR

noticed occupied Coleophoridae larval cases and feeding damage on *Fragaria* (Figs 1, 2). These spatulate cases at first impression had a shape similar to cases of *Coleophora albicostella*, and given the host plant, led to the assumption that this was the rare *C. albicostella*. However, rearing was unsuccessful, leaving the identifications unconfirmed. In the autumn of that same year, again spatulate cases were found, this time at locality 'L2_Birch'. At that time rearing was not attempted. It was assumed to be easier to look for larval cases in the spring and attempt to rear those, allowing the larvae to hibernate under natural conditions. However, in the spring of 2012 JvR encountered no cases and only in the next autumn, JvR observed cases again.

In the autumn of 2012 at locality 'L2_Birch' we stumbled upon a small *Rosa* sp. bush with almost each leaf occupied by a *Coleophora* case, and most leaves were eaten out. At the same locality, a few meters further, we discovered a *Fragaria vesca* plant also with typical *Coleophora* feeding traces and with cases indistinguishable from the ones on the *Rosa* sp. bush. Both even showed the small, approximately three mm long, rectangular shaped first stage cases still present on the plants (Figs 3–6). Only three cases were found on *F. vesca* and JvR decided to return in the spring to collect cases rather than to attempt to hibernate and rear these cases.

However, in the spring of 2013 again JvR found no larval cases on *Fragaria*. It took until October 2013 until finally JvR could collect cases. At this point collaboration started with CD to use DNA barcode analysis to identify the species that creates these cases on *Fragaria* and *Rosa*. To collect fresh material, we intensified the search for larval cases and this yielded two cases from *Rosa* spp. as well as from *Fragaria vesca* from different localities (Table 1). During this collecting effort, we found a second type of feeding trace and larval *Coleophora* case on *F. vesca*: tiny fleck mines created by larvae in small pistol-shaped cases (Figs 7–8) at locality 'L1_Oak'. We sequenced a total of ten larvae (see Figs 8–10) from the different localities on 19.x.2013 and 29.x.2013 (Table 2).

DNA barcode analysis

Nine out of the ten barcoded specimens yielded a DNA barcode. All identifications were unambiguous (Table 2). None of the specimens proved to be *Coleophora albicostella*. Instead, a mixture of three other species, none of which had been recorded to feed on *Fragaria*, was found: *C. gryphipennella* (Hübner, 1796), *C. lutipennella* (Zeller, 1838), and *C. flavipennella* (Duponchel, 1843). The

Table 2. Material collected for DNA barcoding and subsequent molecular identification.

Date	Loc. name	Case type	Host	RMNH number	DNA barcode identification
19.x.2013	L2_Birch	Spatulate	*Fragaria vesca*	RMNH.INS.544235	*C. gryphipennella*
29.x.2013	L1_Oak	Spatulate	*Fragaria vesca*	RMNH.INS.544234	*C. gryphipennella*
29.x.2013	L1_Oak	Spatulate	*Fragaria vesca*	RMNH.INS.544233	*C. gryphipennella*
19.x.2013	L2_Birch	Spatulate	*Rosa* sp.	RMNH.INS.558006	*C. gryphipennella*
29.x.2013	L1_Oak	Spatulate	*Rosa* sp.	RMNH.INS.544232	failed
29.x.2013	L1_Oak	Spatulate	*Rosa pimpinellifolia*	RMNH.INS.558007	*C. gryphipennella*
29.x.2013	L1_Oak	Pistol	*Fragaria vesca*	RMNH.INS.544236	*C. lutipennella*
29.x.2013	L1_Oak	Pistol	*Fragaria vesca*	RMNH.INS.544237	*C. lutipennella*
29.x.2013	L1_Oak	Pistol	*Fragaria vesca*	RMNH.INS.544239	*C. lutipennella*
29.x.2013	L1_Oak	Pistol	*Fragaria vesca*	RMNH.INS.544238	*C. flavipennella*

Figures 1–8. 1. Spatulate case found on *Fragaria* 20.v.2011. To the right of the case feeding damage can be seen. **2.** Spatulate case found on *Fragaria* 20.v.2011, with larva. **3.** First stage case on *Fragaria*, showing also the place where the leaf was cut for a second stage case, 02.x.2012. **4.** Spatulate case on *Fragaria*, 02.x.2012. **5.** *Fragaria* leaf from Figure 3 showing feeding damage, first stage case and 'leaf cut', 02.x.2012. **6.** First stage cases and spatulate cases on *Rosa*, 02.x.2012. **7.** Tiny fleck mines on *Fragaria*, 29.x.2013. **8.** Small pistol case on *Fragaria*, 29.x.2013.

larger cases, i.e. >5 mm long, were all of the spatulate type and were identified as *C. gryphipennella*. The smaller cases were pistol shaped. These were either *C. lutipennella* or *C. flavipennella*, species that normally feed on oaks (*Quercus* spp.). We did not find larger pistol shaped cases.

Rearing

We collected a few autumn cases from *Fragaria vesca* in November 2013 for rearing. They hibernated in a garden shed and began feeding on *Fragaria* again in the spring (Figs 11–12). On 21.v.2014 an adult emerged. Based on the external characters we identified it as *Coleophora gryphipennella*, which can be readily distinguished from *C. albicostella* by the lack of a white stripe along the costa (see Figs 13–14). In addition, a fresh case collected by Luc Knijnsberg on *F. vesca* on 7.v.2014 (Fig. 15) at 'L1_Oak' also successfully yielded an imago of *C. gryphipennella* on 10.vi.2014 (Fig. 16).

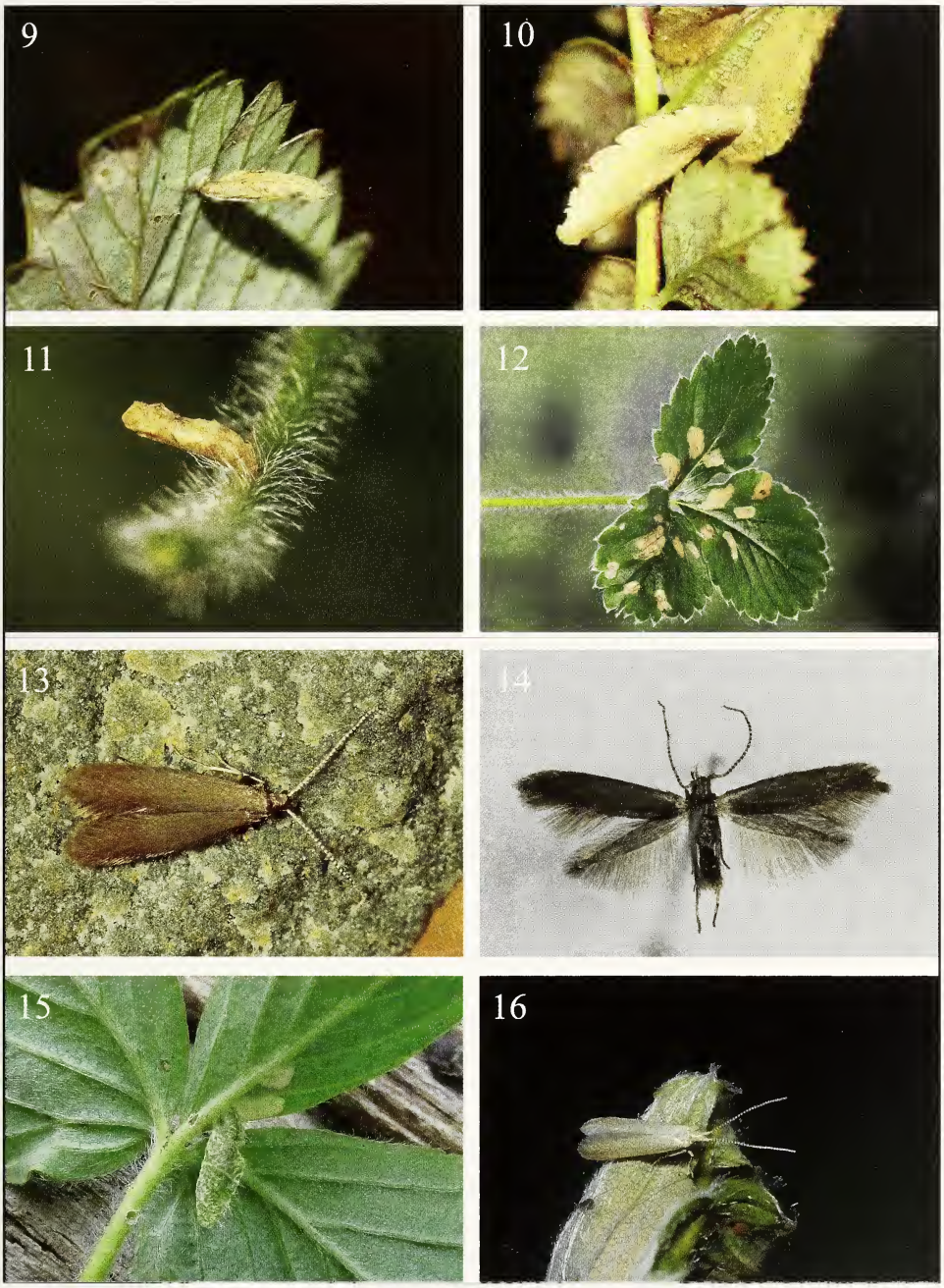
Discussion

Host range and distribution of *Coleophora albicostella*

We initially expected to have found the rare *Coleophora albicostella* in the North Holland Dune Reserve, but none of the specimens that we reared or analysed for DNA proved to be *C. albicostella*. Although this does not completely exclude the option that *C. albicostella* occurs on *Fragaria vesca* in the coastal dunes of The Netherlands, further investigation of the host records of this species made it even more unlikely. *Fragaria* spp. is first mentioned as a host plant for *C. albicostella* by Hering (1957), along with *Potentilla* spp. and *Rubus* spp. The status and source of these observations are unclear, as they are mentioned without reference to the stage (e.g. larval or adult stage) of the studied material or whether rearing was attempted. Hering (1957) does provide a drawing of the larval case, which appears as a rather general looking spatulate case that cannot be distinguished from, for example, *C. gryphipennella*. Furthermore, the case may include slight differences based on the host plant that was included in its construction. Huemer (1988) only mentions *Potentilla* spp. and occasionally also *Comarum* spp., *Filipendula* spp., *Rubus* spp., and *Sanguisorba* spp. as hosts (all Rosaceae). Rearing has been documented from *Potentilla* spp. (Bryner 2015; Richter 2015) and *Geum* spp. (Hugo van der Wolf, pers. comm., in collection). We believe that these records represent the predominant hosts. Even if *C. albicostella* may feed on the other genera, it is likely only so in areas where *Potentilla* or *Geum* may be found. In any case, also in the light of our findings here, *C. albicostella* cannot readily be reported when spatulate larval cases are encountered on *Fragaria* and should always be reared, or DNA barcoded, to efficiently identify such larvae.

Fragaria vesca as a new host for *Coleophora gryphipennella*

We demonstrated both by DNA analysis on the larvae from spatulate shaped larval cases collected on *Fragaria vesca* in the fall as well as by successfully rearing adults from larvae that have been feeding on *F. vesca* both in the fall and in the spring that *F. vesca* is a novel host for *Coleophora gryphipennella*. At least in the study area, this seems unlikely to be due to a shortage of *Rosa*, especially *Rosa pimpinellifolia* L. but also larger species such as *Rosa rubiginosa* L. are abundant and *C. gryphipennella* can be found in many localities feeding on *Rosa* throughout the habitat. The adaptation to another host plant for *C. gryphipennella* could be a local habit, only occurring in



Figures 9–16. 9. Spatulate leaf case on *Fragaria* collected for DNA analysis, 29.x.2013. **10.** Spatulate leaf case on *Rosa* collected for DNA analysis, 29.x.2013. **11.** Final, trivalved case of the reared larva after hibernation and after feeding ended on 05.v.2014. **12.** Fleck mines produced by the reared larva after hibernation and after feeding ended on 05.v.2014. **13.** Emerged imago *Coleophora gryphipennella* reared from a hibernating larva. **14.** Emerged imago *Coleophora gryphipennella* reared from a hibernating larva. **15.** Fresh green case on *Fragaria*, 07.v.2014, leg. and photograph Luc Knijnsberg. **16.** Emerged imago from the case found on 07.v.2014, photograph Luc Knijnsberg.

the dunes of the North Holland Dune Reserve. On the other hand, it could also be a more general, widespread habit that can be found throughout its distribution in Europe. More evidence to support this came from a recent find of a *C. gryphipennella* larva on *F. vesca* near Durbuy, Belgium (Steve Wullaert, pers. comm.), as confirmed by DNA analysis (RMNH.INS.30422 on BOLD). *C. gryphipennella* is distributed throughout most of Europe, Turkey, and Central and Eastern Siberia (Baldizzone et al. 2006). *C. gryphipennella* is mostly described as monophagous on *Rosa* spp. Our observations include feeding signs and larval cases on *Rosa pimpinellifolia* and *Rosa rubiginosa*. *Rubus* sp. and *Rubus corylifolius* Sm. (Rosaceae) are mentioned as incidental host plants by Hering (1957). Hering describes that in the fall the cases are somewhat pressed together sideways and are terminated with a two-sided valve and that in the spring they become more cylindrical, ending with a three-sided valve. Our observations are that after hibernation, the cases are still flat with a two-sided valve. Before pupation they turn more cylindrical with a three-sided valve.

Status of *Coleophora albicostella* and *C. gryphipennella* in The Netherlands

Our findings indicate that *Coleophora albicostella* is rare in The Netherlands, even more rare than it appeared before we started working on this manuscript, and we have had to conclude that some of the records in the national database "NOCTUA" (Ellis 2015a) involved different species. In some cases this was due to identifications based on larval cases, but sometimes also because of a confusion with the similarly named *C. albicosta* (Haworth, 1828), which feeds on *Ulex* spp. (Fabaceae). Only a handful of verified *C. albicostella* records remain, all from the southernmost part of the country, the south of the province of Limburg. Outside this area, two doubtful records are reported, one from the southwest and one from the east of the country. *C. gryphipennella* on the other hand is abundant in The Netherlands with records throughout the country in all provinces (Küchlein and Donner 1993; Muus 2015). Most records are reported from the coastal area where *Rosa pimpinellifolia* is common, which is also reported to be the main host plant (Hering 1957).

Identification of spatulate-type *Coleophora* cases on *Fragaria vesca*

Spatulate cases on *Fragaria* in the spring or the larger cases in the autumn are most likely all *Coleophora gryphipennella*, although we cannot completely exclude *C. albicostella*. It appears that the final cases in the spring are trivalved (see Fig. 11) and from this stage the adults emerge about a month later (Fig. 15). Small pistol cases (i.e. <5 mm) that may be encountered in the autumn on *Fragaria* are *C. lutipennella* or *C. flavipennella*, and can most likely be found in the vicinity of oaks (*Quercus* spp.), the common host for these species (Hering 1957). *C. lutipennella* and *C. flavipennella* are in the same species group as *C. gryphipennella* (*sensu* Emmet et al. 1996), but we find it unlikely that they can complete their larval stage without oaks. It is more likely that, when they come down from the oaks in the autumn to find a safe place to hibernate, they consume small amounts of *Fragaria* opportunistically.

Conclusions

Fragaria is a new host genus for *Coleophora gryphipennella*, which was previously only reported to feed on *Rosa*, or occasionally on *Rubus*. *C. gryphipennella* creates spatulate type cases that may be found in the fall and the spring and the species can complete its larval life on *Fragaria vesca*. Small pistol shaped cases that may be found on *Fragaria* in the fall belong to the *Quercus* feeding species *C. flavipennella* or *C. lutipennella*. The actual host range of *C. albicostella*, which was

initially known to be the only species creating spatulate cases on *Fragaria*, remains unclear, but there are no confirmed rearing records of this species from *Fragaria*.

Acknowledgements

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Book Review: *Eucosma* Hübner of the Contiguous United States and Canada (Lepidoptera: Tortricidae: Eucosmini)

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Donald Wright and Todd Gilligan (2015): *Eucosma* Hübner of the Contiguous United States and Canada (Lepidoptera: Tortricidae: Eucosmini). Wedge Entomological Research Foundation. 256 pp. ISBN 978-0-933003-16-3. Price: €90 or £65.[1]

Donald Wright is Professor Emeritus at the University of Cincinnati and Todd Gilligan is Research Scientist at Colorado State University. Both are renowned tortricid experts and they have already co-authored several publications on the taxonomy and phylogeny of the tortricid subfamily Olethreutinae, with special reference to the tribe Eucosmini and more concretely of its type genus *Eucosma* Hübner.

Figure 1. The cover of the book.

The genus *Eucosma*, with more than 230 species, is one of the most species-rich genera of tortricids. Mostly Holarctic in distribution it is especially diverse in the Nearctic. It has been considered as one of the most taxonomically recalcitrant genera, full of difficulties and misidentifications. Most North American species of *Eucosma* have been historically placed in the genus *Phaneta* and the limits between these two genera and *Pelochrista* have remained obscure. The recent research by these same authors on this extremely difficult taxonomic area has been absolutely critical and the present classification of the group can only be understood through their contribution. In the words of the authors themselves, "This volume is, in part, a culmination of that study". No comprehensive treatment of the North American *Eucosma* had been attempted since Heinrich's (1923) monograph on the "Eucosminae" and so this publication comes to fill an important gap in the lepidopterological literature (Fig. 1).

1 Published by the Wedge Entomological Research Foundation (New Mexico, USA), the book is distributed in Europe through Antiquariat Goecke & Evers (Germany) as well as Pemberley Natural History Books (UK).

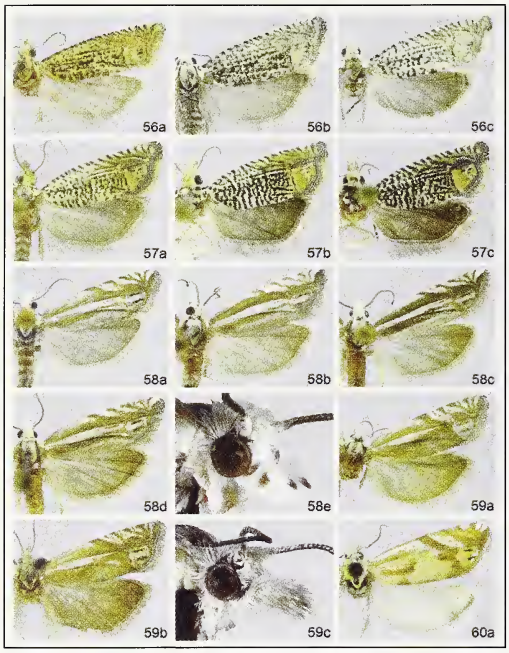

Figure 2. One of the adult habitus plates from the book.

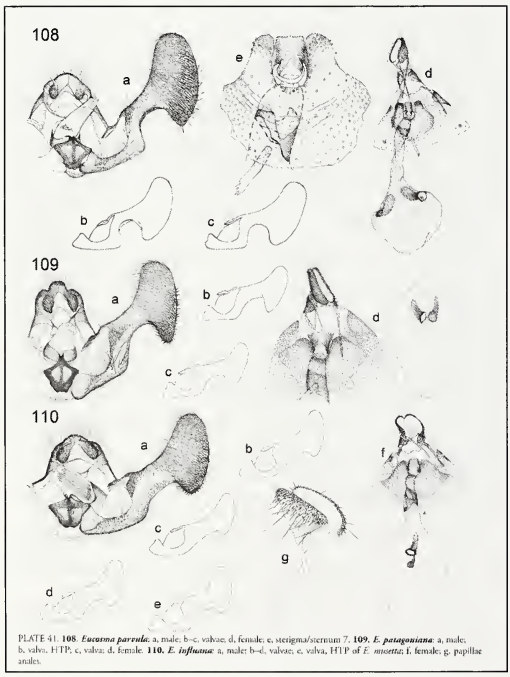

Figure 3. One of the genitalia plates from the book.

Wright and Gilligan concentrate their knowledge of North American *Eucosma* in a monograph of 256 pages, 115 of them beautifully illustrated. The layout of the book is impeccable. An introduction to the genus provides a useful historical background. Those interested in describing or interpreting the morphology of Eucosmini will find especially useful the methodological section that includes an account of the morphology with an interesting character coding. The 133 species – including nine new species – studied are distributed into 18 groups plus a miscellaneous group of non-assigned species. Every group is briefly introduced. Each species is then examined in detail including a list of synonyms, records and misidentifications, type deposition, diagnostic comments, and distributional and biological data when available. Habitus images of the adults (right side) are illustrated in 29 full colour plates (Fig. 2). The head is also photographed when distinctive characters are relevant. Male and female genitalia drawings are compiled in 49 plates where Wright feels free to demonstrate his outstanding qualities as illustrator (Fig. 3). The sterigma-sternum 7-ductus bursae complex is figured separately at a useful scale, allowing accurate details of the female genitalia. Unlike other faunal works, the variability receives special attention and the male genitalia of different specimens are illustrated when necessary, completing a total of 450 adult images and 629 genitalia drawings. The usual appendices (food plants, taxon names…) include a novel and interesting comparative biometric table.

The book is essential for those interested in Tortricidae. But even if focused on the North American fauna and a single genus, anyone interested in Lepidoptera will find this publication attractive, not only for the information provided, but also as a benchmark to which other authors can aspire.

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Book Review: The Notodontidae of South Africa

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Alexander Schintlmeister and Thomas J. Witt 2015: The Notodontidae of South Africa including Swaziland and Lesotho (Lepidoptera: Notodontidae). Proceedings of the Museum Witt, Volume 2, Munich and Vilnius. 104 distribution maps, 37 colour plates, 42 plates with genitalia figures, 288 pages. ISBN: 978-3-940732-19-4. Price €89 plus additional postage.[1]

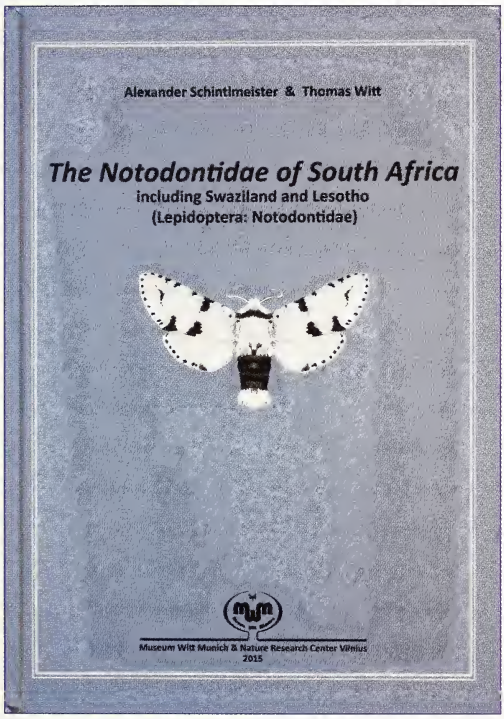

Figure 1. The cover of the book "The Notodontidae of South Africa including Swaziland and Lesotho (Lepidoptera: Notodontidae)".

It came as something of a surprise to see this book. Well-illustrated taxonomic works on the Lepidoptera of sub-Saharan Africa are seldom seen. It is nicely bound in A4 format; often such publications are only available on the Internet, which has the advantage of availability at low cost, but a book still has much appeal if it can be afforded. More of a surprise, when reading the introduction, was that it appears to have been conceived only in 2013. A colossal amount of work must have been put in preparing text and photographs to a high standard.

The Introduction sets out clearly the way in which species are to be described, then follows an historical account of the study of these moths in South Africa with biographical details of the chief contributors. Much of the material described is in the Ditsong National Museum of Natural History (formerly the Transvaal Museum) in Pretoria.

A checklist of the 99 species treated follows with 44 names reduced to synonymy which is as important as the twelve new species and three genera which are described.

1 The book can be ordered online from the Museum Witt Munich website (http://www.insecta-web.org/MWM/htmls/museum_proceedlings_en.html).

The taxonomic part, including description or redescription of each species, fills the main part of the book. Each species has the original description cited and is then described under the headings: diagnosis, bionomics, and distribution. A dot distribution map is included in each case, which includes all the countries of Southern Africa north to the Zambezi River. In critical cases the descriptions are augmented with illustrations pointing out the differences between closely related species. For newly described species the label data of the type series is given in full. There follows a full list of references and a list of the taxonomic changes introduced.

The genitalia figures, occupying 81 pages, are photographs in monochrome, male and female of the same species alongside each other; in many cases the posterior segments of the male abdomen are also illustrated. The colour plates of adults show life size specimens on a uniform pale blue-grey background in most cases and are of high quality. For some species there are also photographs of blown larvae; the data relating to each specimen illustrated are cited in full.

Colour photographs of live specimens and of larvae of some species follow filling the next six plates, then there are photographs of many of the habitats referred to in the text, indicated also by adjoining maps.

This work has been well researched, the taxonomic treatment is thorough and well documented and sensible choices have been made about what information should be included.

For anyone working in Southern Africa this book will be a huge asset and it should also be of interest to those farther afield who are interested in this family. I commend it wholeheartedly.

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Enantiomers of 2-butyl 7*Z*-dodecenoate are sex attractants for males of *Adscita mannii* (Lederer, 1853), *A. geryon* (Hübner, 1813), and *Jordanita notata* (Zeller, 1847) (Lepidoptera: Zygaenidae, Procridinae) in Italy

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Abstract. The R- and S-enantiomers of 2-butyl (7*Z*)-dodecenoate (alone or in mixtures), recently identified in the natural extracts of *Illiberis rotundata* pheromone glands, were used as lures in sticky traps to study the occurrence of Procridinae species in Italy in 14 localities during 2010 and 2011. Three species were attracted during the study – *Adscita mannii* (Lederer, 1853), *A. geryon* (Hübner, 1813), and *Jordanita notata* (Zeller, 1847). The most numerous species was *A. mannii*. Lures with (2*S*)-butyl (7*Z*)-dodecenoate attracted males of *Adscita mannii* and *A. geryon*, while those containing (2*R*)-butyl (7*Z*)-dodecenoate attracted males of *Jordanita notata*.

Introduction

Four pheromone compounds were identified in extracts of female sex pheromone glands of *Illiberis* (*Primilliberis*) *rotundata* Jordan, 1907: (2*R*)-butyl (7*Z*)-dodecenoate [R-7-12], (2*S*)-butyl (7*Z*)-dodecenoate [S-7-12], (2*R*)-butyl (9*Z*)-tetradecenoate [R-9-14] and (2*S*)-butyl (9*Z*)-tetradecenoate [S-9-14] (Subchev et al. 2009). Mixtures of two of them, R-7-12 and R-9-14, were found to be attractive for the males of *I. rotundata* and *I.* (*P.*) *pruni* Dyar, 1905 (Subchev et al. 2012; 2013). Our experience with the use of all four components in Bulgaria, Crimea, Hungary, Armenia, Turkey, and Afghanistan (Efetov et al. 2008, 2010a, 2010b, 2011; Efetov et al. 2014; Subchev 2014; Subchev et al. 2010) showed that only R-7-12 and S-7-12 and their mixtures were attractive for different species of the genera *Rhagades* Wallengren, 1863, *Zygaenoprocris* Hampson, 1900, *Adscita* Retzius, 1783, and *Jordanita* Verity, 1946. Thus, during our field trips in Italy in 2010 and 2011 we used only the last two mentioned substances.

Zygaenidae fauna of Italy is represented by 45 species, of which 14 belong to the subfamily Procridinae (Bertaccini and Fiumi 1999; Efetov 1994, 2004; Efetov and Tarmann 1999, 2000, 2014; Efetov et al. 2011). The aim of our work was to check the attractiveness of R-7-12 and S-7-12 and their mixtures for Italian species of Procridinae.

Materials and methods

The pheromone compounds were synthesized at the Institute of Organic Chemistry, Hamburg University, and pheromone baits and traps were prepared at the Institute of Zoology, Bulgarian Academy of Sciences. For pheromone baits we used penicillin vial caps of grey rubber on which the synthetic pheromone compounds were applied as hexane solutions. After evaporation of the solvent, the caps were wrapped in aluminium foil and kept in a refrigerator at 5 °C until ready for use. In most cases, sticky Delta traps were used. The removable sticky layers were covered with Tanglefoot® insect glue. In addition to the sticky traps we also used commercially available traps (plastic cylinders) for obtaining living material. Moreover, in some localities we also collected attracted specimens by netting them.

Traps baited with the synthetic Procridinae sex pheromone compounds R-7-12 and S-7-12 alone and in mixtures were placed and inspected in the field in 14 habitats located from northern Italy (Alps) to the southern part of the country (Calabria) during the periods 9.vi–18.vi.2010 and 28.vi–8.vii.2011. During these two periods the first two authors travelled from the Alps to southern Italy and placed traps in position during the southwards trip and checked them on the return trip northwards (Efetov et al. 2012).

List of studied localities in Italy (Figs 1–3)

2010

Province L'Aquila, Rocca di Mezzo, 1322 m, traps placed 9.vi.2010, traps inspected 9.vi. and 17.vi.2010.

Province L'Aquila, Sperone, 1212 m, placed 9.vi.2010, inspected 9.vi., 17.vi. and 18.vi.2010.

Province Latina, Lenola, 534 m, placed 10.vi.2010, inspected 10.vi. and 16.vi.2010.

Province Napoli, Monte Faito, 843 m, placed 11.vi.2010, inspected 11.vi.2010.

Province Potenza, Roccarossa, 1370 m, placed 12.vi.2010, inspected 12.vi., 13.vi. and 15.vi.2010.

Province Potenza, Monte Pollino, 1206 m, placed 13.vi.2010, inspected 13.vi., 14.vi. and 15.vi.2010.

Province Cosenza, Lago Ampollino, 1308 m, placed 15.vi.2010, inspected 15.vi.2010.

2011

Province Verona, Monte, 316 m, placed 28.vi.2011, inspected 8.vii.2011.

Province Bologna, Loiano NNW, 248 m, placed 28.vi.2011, inspected 8.vii.2011.

Province Potenza, Roccarossa, 1370 m, placed 30.vi.2011, inspected 3.vii., 4.vii. and 5.vii.2011.

Province Cosenza, Lago Ampollino, 1308 m, placed 30.vi.2011, inspected 1.vii., 2.vii. and 3.vii.2011.

Province Potenza, Lagonegro NE, 1340 m, placed 4.vii.2011, inspected 4.vii. and 5.vii.2011.

Province Chieti, Castiglione Messer Marino N, 873 m, placed 5.vii.2011, inspected 6.vii.2011.

Province L'Aquila, Capistrello (1), 757 m, placed 6.vii.2011, inspected 7.vii.2011.

Province L'Aquila, Capistrello (2), 911 m, placed 6.vii.2011, inspected 7.vii.2011.

Province Roma, Cervara di Roma, 1127 m, locality visited on 7.vii.2011.

Province Roma, Jenne, 936 m, locality visited on 7.vii.2011.

Province Trento (Trentino), Monte Bondone, 967 m, trap placed 9.vii.2011, inspected 9.vii.2011.

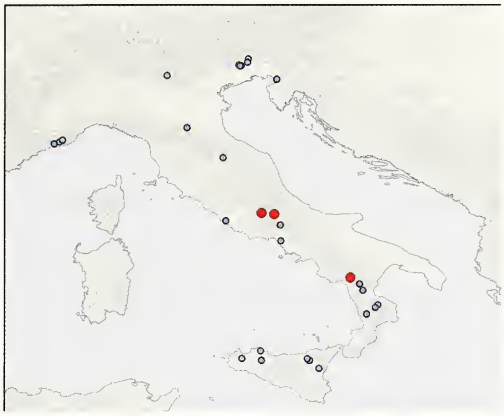

Figure 1. Distribution of *Jordanita notata* in Italy (blue dots) and studied localities with attracted specimens (red dots).

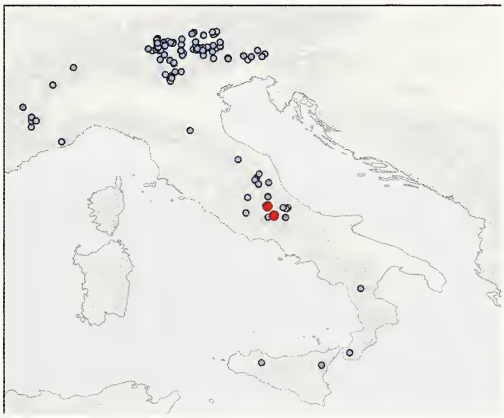

Figure 2. Distribution of *Adscita geryon* in Italy (blue dots) and studied localities with attracted specimens (red dots).

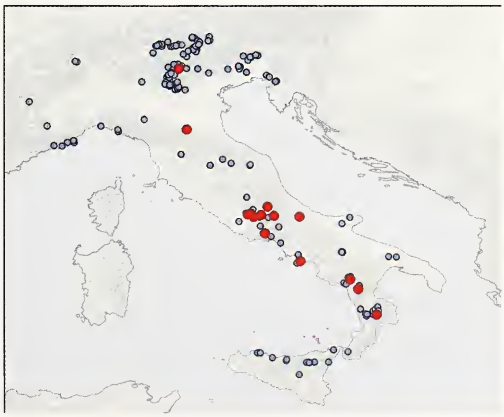

Figure 3. Distribution of *Adscita mannii* in Italy (blue dots) and studied localities with attracted specimens (red dots).

Results

Three Procridinae species were attracted to R-7-12 and S-7-12 and their mixtures (Figs 1–3), viz. *Adscita* (*Tarmannita*) *mannii* (Lederer, 1853), *A.* (*Adscita*) *geryon* (Hübner, 1813), and *Jordanita* (*Tremewania*) *notata* (Zeller, 1847). *Jordanita notata* males (9 specimens) were attracted to R-7-12 or mixtures containing this compound in two habitats in the province of L'Aquila and one habitat in the province of Potenza (Fig. 4, Table 1). *Adscita geryon* males (4 specimens) were attracted in two habitats in the province of L'Aquila (Table 2). *A. mannii* males (136 specimens) were attracted to S-7-12 or mixtures containing this compound in the provinces of Trentino, Bologna, L'Aquila, Roma, Latina, Chieti, Napoli, Potenza, and Cosenza (Fig. 5, Table 3). Twelve specimens of *A. mannii* in the habitats Sperone (2010), Cervara di Roma (2011), and Jenne (2011) were attracted to the box containing all substances immediately after opening the bag, which is why they were not included in Table 3.

When all three variants of the attractant were present in the habitat (S-7-12, R-7-12 and their mixture), *A. mannii* came mainly to S-7-12 (up to 38 males were attracted to one trap over a period of three days at Roccarossa). When we had only R-7-12 and the mixture of R-7-12 and S-7-12, some specimens were also in traps containing the mixture. Furthermore, in Monte Pollino (2010) and Loiano (2011) where *A. mannii* was abundant and where we placed only one trap baited with R-7-12, we found one and five males respectively in the traps (Table 3).

Figure 4. Sticky trap baited with R-7-12 with two males of *Jordanita notata*, Roccarossa, 15.vi.2010.

Table 1. Males of *Jordanita notata* attracted.

		Roccarossa	
Traps placed / control	R-7-12	R-7-12:S-7-12 (1:0.5)	–
12.vi / 13.vi.2010	1	0	–
13.vi / 15.vi.2010	2	0	–
		Sperone	
Traps placed / control	–	R-7-12:S-7-12 (1:0.5)	R-7-12:S-7-12 (1:1)
09.vi / 17.vi.2010	–	3	0
		Sperone	
Traps placed / control	R-7-12	R-7-12:S-7-12 (1:0.5)	–
18.vi / 18.vi.2010	0	1	–
		Roccarossa	
Traps placed / control	R-7-12	S-7-12	R-7-12:S-7-12 (1:1)
30.vi / 03.vii.2011	0	0	0
		Roccarossa	
Traps placed / control	R-7-12	–	R-7-12:S-7-12 (1:1)
03.vii / 04.vii.2011	1	–	0
		Capistrello (1)	
Traps placed / control	R-7-12	–	R-7-12:S-7-12 (1:1)
06.vii / 07.vii.2011	1	–	0

Table 2. Males of *Adscita geryon* attracted.

		Rocca di Mezzo	
Traps placed / control	R-7-12	S-7-12	–
09.vi / 09.vi.2010	0	1	–
		Sperone	
Traps placed / control	–	R-7-12:S-7-12 (1:0.5)	R-7-12:S-7-12 (1:1)
09.vi / 17.vi.2010	–	1	0
		Sperone	
Traps placed / control	R-7-12	R-7-12:S-7-12 (1:0.5)	–
18.vi / 18.vi.2010	0	2	–

Table 3. Males of *Adscita mannii* attracted.

		Roccarossa	
Traps placed / control	R-7-12	R-7-12:S-7-12 (1:1)	S-7-12
30.vi / 03.vii.2011	0	0	38
		Lagonegro	
Traps placed / control	R-7-12	R-7-12:S-7-12 (1:1)	S-7-12
04.vii / 04.vii.2011	0	0	1
		Castiglione Messer Marino	
Traps placed / control	R-7-12	R-7-12:S-7-12 (1:1)	S-7-12
05.vii / 06.vii.2011	0	1	3
		Capistrello (2)	
Traps placed / control	R-7-12	R-7-12:S-7-12 (1:1)	S-7-12
06.vii / 07.vii.2011	0	0	1

		Roccarossa	
Traps placed / control	R-7-12	R-7-12:S-7-12 (1:0.5)	–
12.vi / 12.vi.2010	1	9	–
12.vi / 13.vi.2010	0	1	–
13.vi / 15.vi.2010	0	4	–
		Monte Pollino	
Traps placed / control	R-7-12	R-7-12:S-7-12 (1:0.5)	–
13.vi / 13.vi.2010	0	15	–
13.vi / 14.vi.2010	0	3	–
		Lenola	
Traps placed / control	R-7-12	R-7-12:S-7-12 (1:0.5)	–
11.vi / 16.vi.2010	1	0	–
		Sperone	
Traps placed / control	R-7-12	R-7-12:S-7-12 (1:0.5)	–
18.vi / 18.vi.2010	0	4	–
		Lago Ampollino	
Traps placed / control	R-7-12	R-7-12:S-7-12 (1:1)	–
15.vi / 15.vi.2010	0	2	–
		Roccarossa	
Traps placed / control	R-7-12	R-7-12:S-7-12 (1:1)	–
03.vii / 05.vii.2011	0	1	–
		Lago Ampollino	
Traps placed / control	R-7-12	R-7-12:S-7-12 (1:1)	–
30.vi / 01.vii.2011	0	1	–
		Capistrello (1)	
Traps placed / control	R-7-12	R-7-12:S-7-12 (1:1)	–
06.vii / 07.vii.2011	0	3	–
		Monte Faito	
Traps placed / control	–	R-7-12	S-7-12
11.vi / 11.vi.2010	–	0	4
		Sperone	
Traps placed / control	–	R-7-12:S-7-12 (1:0.5)	R-7-12:S-7-12 (1:1)
09.vi / 09.vi.2010	–	1	1
09.vi / 17.vi.2010	–	3	1
		Monte Pollino	
Trap placed / control	R-7-12	–	–
15.vi / 15.vi.2010	1	–	–
		Loiano	
Trap placed / control	R-7-12	–	–
28.vi / 08.vii.2011	5	–	–
		Rocca di Mezzo	
Trap placed / control	–	R-7-12:S-7-12 (1:0.5)	–
17.vi / 17.vi.2010	–	1	–
		Lenola	
Trap placed / control	–	R-7-12:S-7-12 (1:1)	–
16.vi / 16.vi.2010	–	5	–
		Roccarossa	
Trap placed / control	–	–	S-7-12
12.vi / 12.vi.2010	–	–	1
		Monte Bondone	
Trap placed / control	–	–	S-7-12
09.vii / 09.vii.2011	–	–	12

Figure 5. Sticky trap baited with S-7-12 with 38 males of *Adscita mannii*, Roccarossa, 3.vii.2011.

Discussion

A. mannii is distributed from north-eastern Spain and south-western France through the southern parts of central Europe, Italy (including Sicily) and the Balkans to eastern Romania, Greek islands (except Crete), and north-western Turkey. *A. geryon* is known from the Iberian Peninsula and Great Britain (England, Wales) through most of central and southern Europe to Moldavia, south of European Russia and north-western Turkey. *J. notata* is distributed in western and central Europe, northern Mediterranean (including Sicily and Crete) to Ukraine, Crimea, Northern Caucasus, Transcaucasia, Turkey, and north-western Iran (Efetov and Tarmann 1999; Efetov 2004). The distributions of these three species in Italy are shown in Figs 1–3 (blue dots).

Our results confirm the data obtained earlier in Bulgaria and the Crimea that R-7-12 is an attractant for *Jordanita notata*, while S-7-12 attracts *Adscita geryon* and *A. mannii* (Subchev et al. 2010). It is interesting to note that the presence of S-7-12 does not inhibit the attractiveness of R-7-12 for *J. notata* and the presence of R-7-12 also does not influence the attractiveness of S-7-12 for *A. geryon* and *A. mannii*. In July 2007, during an expedition to Armenia, K. A. Efetov and V. M. Kiselev obtained the opposite result with *Zygaenoprocris taftana* (Alberti, 1939) (Efetov et al. 2011), a species from the subgenus *Molletia* Efetov, 2001, which was attracted to R-7-12, while

the presence of S-7-12 completely cancelled the attractiveness of R-7-12. This means that S-7-12 is an inhibitor of R-7-12 for *Z. taftana*. The genus *Zygaenoprocris* is represented by four subgenera (Efetov 2001a; 2001b). It looks as though the same situation as found in *Molletia* is present in two species of another subgenus, viz. *Zygaenoprocris* Hampson, 1900. During an expedition to Afghanistan in July 2011 A. Hofmann attracted *Zygaenoprocris* (*Zygaenoprocris*) *eberti* (Alberti, 1968) and *Z.* (*Z.*) *chalcochlora* Hampson, 1900, to R-7-12 and a mixture of R-7-12+R-9-14 (Subchev 2014; Efetov, Hofmann and Tarmann 2014).

Jordanita notata belongs to the subgenus *Tremewania* Efetov & Tarmann, 1999, *Adscita geryon* to the subgenus *Adscita* Retzius, 1783, and *A. mannii* to the subgenus *Tarmannita* Efetov, 2000 (Efetov and Tarmann 1999; Efetov 2004). Additional investigations are necessary to find attractants for representatives of the three other subgenera of Procridinae that inhabit Italy, viz. *Roccia* Alberti, 1954 (one species), *Jordanita* Verity, 1946 (three species), and *Solaniterna* Efetov, 2004 (one species).

It seems that the same attractants can be active for different species of the subgenus, but the attractiveness for different species can depend on the ratio of the components in the mixture. For example, the subgenus *Primilliberis* Alberti, 1954, of the genus *Illiberis* Walker, 1854, includes four species (Efetov 1997; Efetov and Tarmann 2012), and in two of them, viz. *I.* (*P.*) *rotundata* and *I.* (*P.*) *pruni*, the males were attracted by different ratios of R-7-12 and R-9-14 (Subchev et al. 2012; 2013). It is possible that a similar situation can be present in *Adscita* (*Adscita*), *Adscita* (*Tarmannita*) and *Jordanita* (*Tremewania*). The confirmation of this needs further investigations.

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